THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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OCTOBER, 1952

THE PHYSICAL AND MECHANICAL PROPERTIES OF THE COPPER-NICKEL ALLOYS CONTAINING LESS THAN 50 PER CENT. NICKEL *page* 226

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THE PHYSICAL AND MECHANICAL PROPERTIES OF THE COPPER-NICKEL ALLOYS CONTAINING LESS THAN 50 PER CENT. NICKEL

General Physical Properties of the Alloy Series

Equilibrium Diagram

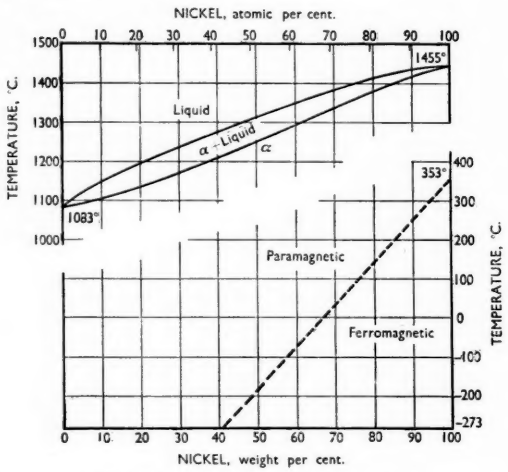

Fig. 1. The Copper-Nickel system.

Specific Gravity

Table I

Specific Gravity of Copper-Nickel Alloys in the Rolled and Annealed Condition

Copper %	Nickel %	Specific Gravity
80	20	8·9620
70	30	8·9312
55	45	8·8935

Electrical Resistivity

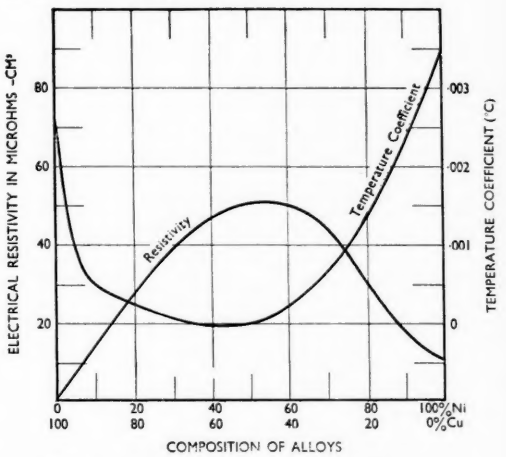

Fig. 2. Electrical Resistivity and Temperature-Coefficient of Copper-Nickel Alloys.

Thermal Expansion

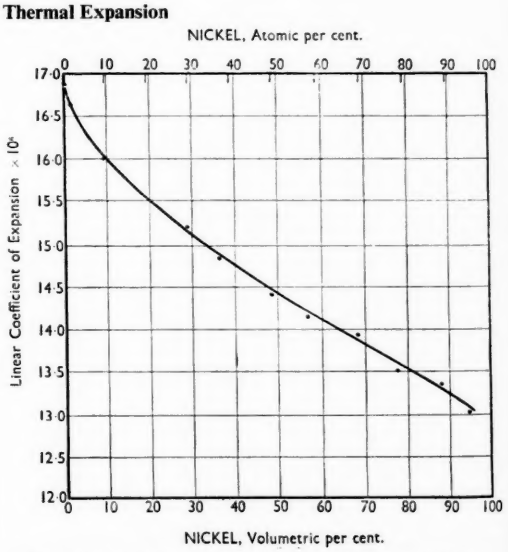

Fig. 3. Coefficient of Expansion of Copper-Nickel Alloys.

Thermal Conductivity

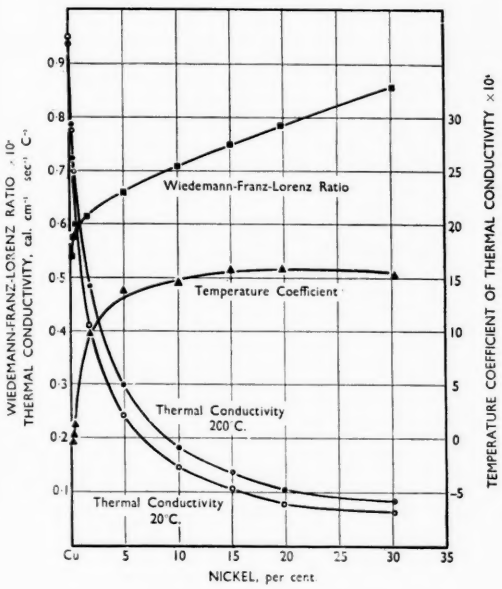

Fig. 4. Thermal Conductivity of Copper-Nickel Alloys Annealed at 800°C.

Specific Heat

Table II

Specific Heat of Copper-Nickel Alloys

Alloy	90% Cu 10% Ni			70% Cu 30% Ni	55% Cu 45% Ni
Temp. °C.	−136	−39	+12	0-100	0-100
Specific Heat Cals/gm./°C. Btu/lb./°F.	0.073	0.087	0.090	0·090	0·098

Colour

The increasing addition of nickel to copper soon causes the latter metal to lose its characteristic salmon-pink colour, and when 15 per cent. of nickel has been introduced the colour is practically white. Still further addition enhances the whiteness and brilliance of the colour, until when the content reaches 40-45 per cent. the polished alloy is difficult to distinguish from sterling silver.

Crystal Structure

Face-centred cubic.

Lattice Parameter

Varies linearly with atomic concentration from 360Å for copper to 354Å for nickel.

Curie Temperature

Varies linearly from 353°C. for pure nickel to −170°C. for an alloy containing 50 per cent. nickel.

Optical Properties

Table III

Optical Properties of Copper-Nickel Alloys

Nickel %	Wavelength = 4,358 A			Wavelength = 5,461 A			Wavelength = 5,780 A		
	Reflectivity %	Refractive Index	Absorption Coefficient	Reflectivity %	Refractive Index	Absorption Coefficient	Reflectivity %	Refractive Index	Absorption Coefficient
0	51·6	0·964	2·03	61·3	0·817	2·27	77·8	0·431	2·39
8·2	51·7	1·04	2·11	64·1	0·940	2·59	70·4	0·800	2·75
17·2	57·7	1·12	2·47	66·5	1·15	3·02	70·3	1·14	3·28
23·2	53·6	1·23	2·37	62·8	1·38	3·03	65·0	1·44	3·25
33·4	54·4	1·33	2·50	61·8	1·56	3·13	63·2	1·68	3·33
43·1	56·1	1·46	2·69	59·9	1·86	3·22	60·2	2·00	3·33

Table IV

Typical Physical and Mechanical Properties at Room Temperature of Commercial Copper-Nickel Alloys

Alloy Cu %	Alloy Ni %	Condition	Typical Mechanical Properties: 0·1% Proof Stress t.s.i.	Ultimate Tensile Strength t.s.i.	Elongation % on $4\sqrt{\text{Area}}$	D.P.N.	Typical Physical Properties: Linear Coefficient of Thermal Expansion millionths per °C.	Thermal Conductivity C.G.S. Units at 20°C.	Electrical-Resistance ohms/cm/cm² at 20°C.	Specific Gravity	Remarks
95	5	Annealed	7	19	55			0·14		8·92	Normally composition is modified by additions of iron up to 1·5% and manganese, and used as a 'copper smithing' alloy for construction of sea water pipe lines where impingement attack is encountered.
		Cold-worked	18	27	12						
90	10	Annealed	10	20	45	90	16	0·11		8·89	Normally composition is modified by additions of iron and manganese of about 2%, and the alloy is used for steam condenser tubing, feed heaters, and other heat exchangers.
		Cold-worked	30	37	10	180					
80	20	Annealed	12	22	45	75	(20°-300°C.) 15·5	0·07		8·96	Used for bullet envelope manufacture and very occasionally for production of condenser and other tubing.
		Cold-worked	30	35	8	140					
75	25	Annealed		25	45	85				8·94	Principal use is for coinage.
		Cold-worked		39	8	150					
70	30	Annealed	11	27	45	85	(20°-300°C.) 16·2	0·06		8·93	Modified by additions of iron and manganese of up to 2% each, is used in the tube form for condensers and other heat exchangers.
		Cold-worked	45	42	8	160					
55	45		(0·2%) 15	32·5	47	156	(20°-300°C.) 15·8	0·054	49	8·88	Used principally as an electrical resistance material on account of its negligible temperature coefficient of electrical resistance ±0·00004 over the range 0°-200°C.

Table V

Mechanical Properties of Selected Copper-Nickel Alloys at High and Low Temperatures

Composition					Condition	Temperature °C.	Tensile Strength t.s.i.	Yield Strength 0·1% Extension t.s.i.	Elongation in 2 in. %	Reduction of Area %	Izod Impact ft.-lb.	Charpy Impact ft.-lb.	Stress for Creep Rates per 1,000 hours of—		
Ni %	Fe %	Mn %	Si %	Others %									0·001% t.s.i.	0·01% t.s.i.	0·1% t.s.i.
9·64	0·85	0·27	0·08	P,0·05	Hot-rolled	Room	21·9	12·9*	34	64		42			
						−134	26·8	14·7*	43	65		56			
						−196	29·7	15·0*	50	62		68			
20·58		0·11	0·03		1-in. rod annealed ..	Room	23·0	12·4	26	78	77				
						−40	26·5	12·9	29	77	81				
						−80	27·5	12·9	29	76	79				
						−114	29·5	13·0	28	75	84				
						−180	32·9	14·5	36	72	85				
29·54		0·57		Zn,0·62	Annealed	Room	25·7	15·3*	54			66			
						−31						59			
						−115						60			
30·06	0·03	0·8		Pb,0·005	0·125 wire, annealed	Room	26·3	9·4*	40				10·7	15·6	
						149							7·1	13·4	
						260									
30·06	0·03	0·8		Pb,0·005	0·125 wire, drawn 84%	Room	40·4	35·7*	9				3·6		
						260									
30·32		0·65		Zn,0·15	0·75-in. rod, annealed 550°C.	30	28·9	21·5*	37	65			4·1	8·4	
						399	20·3		22	48					
45·78	0·07	0·39	0·15	Co,0·26	1-in. rod, annealed ..	Room	26·8	8·7	40	77	80				
						−40	30·2	9·4	43	78	85				
						−80	32·2	9·9	48	75	81				
						−120	34·4	10·8	48	74	83				
						−180	40·0	11·7	57	76	86				

* 0·5% extension.

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Sub-Zero Properties of Metals and Alloys

U.S. DEPT. OF COMMERCE, NAT. BUREAU STANDARDS: 'Mechanical Properties of Metals at Low Temperature.' Circular 520, May 7, 1952; 206 pp.

Report of Proceedings at N.B.S. Semi-Centennial Symposium, May, 1951.

Certain of the papers contributed to this symposium were reported, from abstract source, in *Nickel Bulletin*, 1951, vol. 24, Nos. 9-10, pp. 199-200. Additional papers, now referred to for the first time in this Bulletin, are shown below, together with brief notes on papers of which insufficient details were available at the time of the earlier announcement.

N. P. ALLEN: 'Recent European Work on the Mechanical Properties of Metals at Low Temperatures,' pp. 1-34; disc., pp. 34-5.

A brief report is given of work on this subject done in Europe since 1940. Elasticity and plasticity are considered, and the development of brittleness at low temperatures is discussed in relation to brittle fracture in mild steel, the behaviour of heat-treated alloy steels at temperatures prevailing in the stratosphere, and the reliability of austenitic steels at liquid-air temperature. The low-temperature properties of pure alloys of iron made at the National Physical Laboratory are described, and it is shown that the influence exerted by some alloying additions on the rupture strength is independent of their influence on resistance to plastic deformation.

J. B. AUSTIN: 'Manufacture of Steels for Low-Temperature Service,' pp. 36-44; disc., pp. 45-7.

Transition temperature (tough-to-brittle fracture) depends largely on the microstructure of the steel: the optimum structure appears to be austenite. In ferritic steels tempered martensite has the lowest transition temperature, and coarse pearlite the highest; mixed structures containing pearlite and tempered martensite have an intermediate transition temperature. Other factors which are of significance in relation to low-temperature behaviour are grain size, alloying elements, and mode of deoxidation. The best method of achieving the desired end product depends to a considerable extent on the precise conditions of service which have to be met, and on economic factors.

W. CRAFTS and C. M. OFFENHAUER: 'Development and Application of Chromium-Copper-Nickel Steel for Low-Temperature Service,' pp. 48-63; disc., pp. 63-6; for abstract see *Nickel Bulletin*, 1951, vol. 24, Nos. 9-10, p. 199.

G. W. GEIL and N. L. CARWILE: 'Tensile Properties of Copper, Nickel and Some Copper-Nickel Alloys at Low Temperatures,' pp. 67-93; disc., pp. 93-6 ; for abstract see *Nickel Bulletin*, 1951, vol. 24, Nos. 9-10, p. 200.

J. B. JOHNSON and D. A. SHINN: 'Application of Metals in Aircraft at Low Temperatures,' pp. 97-109; disc., pp. 109-11.

Laboratory tests on standard and on notched specimens of materials used in aircraft components indicate that the permissible design values determined at room temperature are a safe guide for low-temperature operation as encountered by aircraft. This is confirmed by the fact that no reports have been made, from stations operating in cold climates, of failure attributable to a change in mechanical properties of the materials.

Data presented in this paper (for temperatures down to −320° or −420°F. (−196° or −251°C.) cover low- and medium-alloy nickel-containing and other steels, aluminium alloys, magnesium alloys, 18-8 chromium-nickel steel, and titanium. It is urged that, although the impact test gives useful guide as to the temperature of transition from tough to brittle fracture, it should not be used as the sole gauge of sub-zero properties. Change in ductility in a tensile test, as a function of temperature, is considered to be a more comprehensive source of information for the engineer-designer, while the best criterion is a simulated-service test on the actual part or structure, at the lowest temperature expected in routine operation.

V. N. KRIVOBOK: 'Properties of Austenitic Stainless Steels at Low Temperatures,' pp. 134-6.

The author presented a critical study of published and unpublished information on the strength characteristics of austenitic stainless steels at various sub-zero temperatures.

The effect of composition on mechanical properties at room and at low temperatures, calculation of true strength from test results, and the influence of various forms of heat-treatment on mechanical properties at sub-zero temperatures, are discussed in detail. Particular attention is drawn to the beneficial influence of extra-low carbon content.

A large amount of data on modulus of elasticity, fatigue strength, impact and tensile-impact qualities,

effect of notches, distribution of ductility at the notch, etc., is summarized and critically evaluated. The beneficial effect of sub-zero temperatures for mechanical working of austenitic nickel-chromium steel is emphasized.

C. W. MACGREGOR and N. GROSSMAN: 'Dimensional Effects in Fracture,' pp. 137-50; disc., pp. 150-2.

Three phases of the general problem of the effects of dimensional changes of test specimens, on fracture characteristics, are reported: (1) influence of size on transition temperature, tough to brittle; (2) effect of various ratios of combined stresses on the brittle transition temperature; and (3) effect of combined stresses on fracture strength.

R. L. SMITH, G. A. MOORE and R. M. BRICK: 'Mechanical Properties of High-Purity Iron-Carbon Alloys at Low Temperatures,' pp. 153-79; disc., p. 179.

Natural stress-strain data were obtained, over the range $+23°$ to $-185°$C., on four high-purity iron-carbon alloys, containing 0·05 to 0·49 per cent. carbon, and having A.S.T.M. No. 4-5 ferrite grain size, and pearlite of spacing equivalent to that of normalized steels.

M. L. WILLIAMS: 'Brittle Fractures in Ship Plates,' pp. 180-204; disc., pp. 204-6.

The principal factors contributing to structural failures of welded ships, and measures which have been adopted to prevent such failures, are discussed.

S.A.E. Handbook: 1952 Edition

'1952 S.A.E. Handbook.' Published by Soc. Automotive Engineers, Inc., New York, 1952; 946 pp.

This comprehensive volume includes sections on the following subjects:—

Ferrous Metals

S.A.E./A.I.S.I. Steel specifications and standard compositions; general data on treatment and properties of steels; methods of testing steels; ferrous castings; tool and die steels; arc-welding electrodes; production specifications for ferrous materials.

Non-Ferrous Metals

Copper and copper-base alloys, cast and wrought; alloys of aluminium, magnesium, and zinc base; corrosion- and heat-resisting alloys; electrical-resistance alloys; bearing alloys; brazing and soldering materials; wire cloth; electroplating practice.

Hot Machining of High-Alloy Materials

See abstract on p. 242.

Acoustic Method of Determining Intercrystalline Corrosion

O. MASI and A. FERRI: 'Analysis of Metallic Sound as a Method of Test. I. Measurement of Intercrystalline Corrosion in Stainless Steel.' *Metallurgia Italiana*, 1952, vol. 44, June 18, pp. 207-14.

For measurement of intercrystalline corrosion the authors propose a method based on analysis of sound emitted by bars of the steel struck under specified conditions, the nature of the sound emitted being registered on an oscillographic recorder, which is described.

Vibratory Treatment of Stainless Steel during Welding

See abstract on p. 250.

NICKEL

Solubility of Carbon in Nickel

J. J. LANDER, H. E. KERN and A. L. BEACH: 'The Solubility and Diffusion Coefficient of Carbon in Nickel.' *Physical Rev.*, 1952, vol. 85, Jan. 15, p. 389.

Abstract of paper to Amer. Physical Soc., Nov., 1951.

'Weight per cent. solubility of carbon in nickel varies from 0·041 at 780°C. to 0·245 at 1030°C. Values obtained for the diffusion coefficient of carbon in nickel range from $4·0 \times 10^{-9}$ cm² per sec. at 727°C. to $4·1 \times 10^{-7}$ at 1020°C. These values were obtained by a novel method in which carbon coated on one side of a nickel disk is diffused through the disk to react with nickel oxide coated on the other. Rates of diffusion are observed as rates of evolution of the gaseous products of reaction. The initial, steady, and final states predicted by diffusion theory may be accurately observed if proper experimental conditions are satisfied. The results have been applied in an analysis of reactions taking place in oxide-coated thermionic cathodes. It was found in experiments with nickel coated on one side with BaO and on the other with C that rates of reaction between C and BaO were nearly identical with those between NiO and C. Thus the rate-limiting factor in the reactions is the diffusion of carbon through nickel.'

Magneto-Acoustic Effects in Polycrystalline Nickel

S. J. JOHNSON and T. F. ROGERS: 'Magnetically Induced Ultrasonic Velocity Changes in Polycrystalline Nickel.' *Jnl. Applied Physics*, 1952, vol. 23, May, pp. 574-7.

Report of measurements on polycrystalline nickel rods: shear and compressional ultrasonic propagation modes were used throughout the frequency range of 1-10 megacycles. The polycrystalline measurements are compared with data recently published relating to single crystals of nickel. The ΔE effect was found to decrease with increasing frequency throughout the megacycle region, showing general agreement with low-frequency measurements.

Ferromagnetic Domain Structure in Nickel Crystals

U. M. MARTIUS, K. V. GOW and B. CHALMERS: 'Ferromagnetic Domain Structure of Single Crystals and Bicrystals of Nickel.' *Physical Rev.*, 1952, vol. 85, Feb. 15, p. 713.

Abstract of paper to Amer. Physical Soc., Nov., 1951.

'Single crystals and bicrystals of nickel, with predetermined orientation, were grown by the method developed by Chalmers and Gow. The following range of orientation was studied: Crystals which contained two (111) directions in the plane of the

surface, and small deviations from this orientation; crystal with a single (111) direction in the plane of the surface and specimens with a (100) plane as the crystal surface, hence containing no direction of easy magnetization in the plane of the surface. The colloid technique was used to study the domain structure on the carefully electropolished crystal surfaces. The general features of the domain structures are in agreement with the predictions of the theory. The patterns on nickel are very sensitive to small differences in crystallographic orientation. Two effects have been observed in the proximity of small angle crystal boundaries. Changes in domain spacing and new substructures can result directly from the small differences in crystal orientation; also, curvature of the Bloch wall has been found in many patterns. The curvature is attributed to lattice strains associated with the crystal boundaries.'

Deuterized Raney Nickel

N. A. KHAN: 'Preparation of Deuterized Raney Nickel and Selective Deuteration of the Triple Bond.' *Jnl. Amer. Chemical Soc.*, 1952, vol. 74, June 20, pp. 3018-22.

The author describes procedure for preparation of deuterized Raney nickel, for use in deuterating the triple bond selectively to the double bond, with a view to obtaining dideutero-olefinic compounds. Comparative study of hydrogenation and deuteration showed selective deuteration to be as effective as hydrogenation. A method of preparation of a deuterized Raney nickel catalyst, designated W-8, is also described. This catalyst was prepared as free as possible from alkali and alumina, and with a minimum of hydrogen adsorbed on its surface, and was then deuterized by a specially selected process.

Heat Capacity of Nickel

R. H. BUSEY and W. F. GIAUQUE: 'The Heat Capacity of Nickel from 15° to 300°K.: Entropy and Free Energy Functions.' *Jnl. Amer. Chemical Soc.*, 1952, vol. 74, June 20, pp. 3157-8.

The work reported was done in connexion with the requirement for the free-energy function for nickel in an equilibrium study of the reduction of nickel chloride by hydrogen at temperatures up to about 700°K. (427°C.). The material was a very pure nickel, of which the following analysis is given: carbon 0·014, cobalt 0·0018, copper 0·0009, per cent. The following elements were found only in very small traces: aluminium, boron, calcium, iron, magnesium, silicon. The following elements were *not* found: lead, tin, arsenic, silver, sodium, vanadium, zinc.

Thermal Conductivity of Nickel and Other Metals at Low Temperatures

K. MENDELSSOHN and H. M. ROSENBERG: 'The Thermal Conductivity of Metals at Low Temperatures. II. The Transition Elements. *Proc. Physical Soc., Sect. A.*, 1952, vol. 65, June 1, pp. 388-94.

Results of measurements in the range 2° to 40°K. (−271° to −233°C.) for titanium, manganese, iron, nickel, zirconium, niobium, molybdenum, rhodium, palladium, tantalum, tungsten, iridium, platinum, uranium, and for a single crystal of lead. The results are shown in a series of graphs. In general, the metals of Group VIII of the Periodic System have a much higher conductivity than those of earlier groups.

Spectral Emissivity of Nickel and Nickel-Iron Alloys

H. LUND and L. WARD: 'The Spectral Emissivities of Iron, Nickel and Cobalt.' *Proc. Physical Soc., Sect. B.*, 1952, vol. 65, July 1, pp. 535-40.

The spectral emissivities of the three metals were measured by direct comparison of surface and blackbody radiation, at temperatures between 1000° and 1300°C., over the wave length 1·0μ to 2·6μ, using a lead sulphide cell and amplifier as the detecting unit. Values for the temperature coefficients of emissivity referred to 1000°C. indicate an X point for iron at 1·6μ, but none for nickel in this spectral range. Emissivity of nickel was found to vary markedly with temperature: a table shows temperature coefficients for different wavelengths.

In a further section of the investigation, measurements were made on strip of iron-nickel alloys at 10 per cent. intervals of composition: values of emissivity *vs.* composition, for various wavelengths, at 1000°C., are shown. All the curves are of similar form, indicating a maximum at about 60 per cent. nickel. In this case values of temperature coefficient were scattered, and no significant conclusion could be drawn from them.

Spectrophotometric Determination of Nickel in Steel

J. P. MEHLIG and B. J. NEWBY: 'Spectrophotometric Determination of Nickel in Steel with Potassium Dithiooxalate.' *Chemist Analyst*, 1952, vol. 41, June, pp. 28-31.

The method described involves separation by dimethylglyoxime, conversion of the precipitate into the nickelo-dithiooxalate complex, and spectrophotometric estimation of the light transmitted by the latter solution. The results have been found to compare favourably with those obtained by the dimethylglyoxime gravimetric method, and by the ammonia spectrophotometric method. Macro quantities of nickel may also be satisfactorily determined by this procedure. Various ions (commonly occurring in steel) which interfere with the colour systems involved are removed in the course of the analysis.

Chemical Analysis of Nickel and Nickel Alloys: Recommended Procedures

See abstract on p. 236.

Formation of Nickel Carbide by Decomposition of *n*-Hexane

A. CIMINO and G. PARRAVANO: 'Production of Nickel Carbide by Decomposition of *n*-Hexane on Metallic Nickel.' *Jnl. Physical Chemistry*, 1952, vol. 56, June, pp. 706-7.

Experimental data on formation under various conditions of temperature and time of reaction, and discussion of the process involved in formation of nickel carbide under the conditions described.

Nickel-Alkaline Accumulators for Automobiles

M. LAPUYADE: 'Use of Alkaline Batteries for Start-Up of Engines.' *Jnl. Soc. Ingénieurs Automobiles*, 1952, vol. 26, Apr., pp. 107-10; disc., p. 111.

The paper emphasizes the benefits to be derived from the use of this type of battery, describing (*a*) the Blocacier type of battery developed by Société des Accumulateurs Fixes et de Traction about 1930, and (*b*) their more modern type, the 'Alcabloc', which embodies positive plates of sintered nickel.

Thermomagnetic Investigation of Nickel Carbide

R. BERNIER: 'Thermomagnetic Study of Carbides of Iron and of Nickel.' *Annales de Chimie*, 1951, Sér. 12, vol. 6, Jan.-Feb., pp. 104-61. *Brit. Abstracts, B.I.*, 1952, Mar., p. 375.

The author gives a highly detailed description of methods used for preparation of nickel carbide and nickel nitride, from purified materials, and of the investigation of the constitution and properties of the nickel-carbon and nickel-nitrogen systems. Cementite and the iron-nickel-carbon system were also investigated. A comprehensive summary of the observations made is given in *British Abstracts, loc. cit.*

Thermal Decomposition of Nickel Carbonyl

K. TONOSAKI: 'Thermal Decomposition of Nickel Carbonyl. III and IV.' *Jnl. Chemical Soc., Japan*, 1951, vol. 76, pp. 762-3; 796-8. *Chemical Abstracts*, 1952, vol. 46, p. 5942.

III. 'The velocity of thermal decomposition of $Ni(CO)_4$ vapour was studied in various glass vessels having different ratios between the volume and the surface area.'

IV. 'The velocity of thermal decomposition was determined at 60°, 70° and 80° in a soda-glass reaction vessel coated with a nickel film. The mechanism of decomposition is discussed.'

Research on Nickel Salts and Compounds at Mellon Institute

'Research as a Source of New Knowledge. Mellon Institute's Growing Range of Investigations.' *Chemical Age*, 1952, vol. 67, Aug. 2, pp. 145-9.

Review of work at Mellon Institute 1951-52. The following information is given relative to the research on nickel compounds:—

'The Multiple Fellowship (Nickel) of The International Nickel Co., Inc., New York, N.Y., had given most of its research attention to studies of (1) the detergent and other properties of oil-soluble nickel compounds, with the objective of establishing their suitability as lubricant additives, (2) the wetting properties of nickel subsulphide on various catalyst supports, and (3) the effect of varying conditions of precipitation upon the characteristics of nickel hydroxide. The lubricant-additive programme was continued productively from the previous year.

'During the course of the investigation on nickel hydroxide a new method for the study of basic heavy-metal salts was discovered and applied to the basic salts of nickel. Some of the factors influencing the composition and other properties of the basic carbonates of nickel were also clarified, so that a catalyst intermediate having certain predetermined properties could be prepared. This information will constitute the subject matter of several forthcoming publications.

'Less comprehensive projects of the Fellowship have explored nickel-stabilized azo dyes and also isocyanide-substituted nickel-carbonyl compounds.'

Reaction of Fluorine with Nickel and Nickel Compounds: Properties of Nickel Fluoride

H. M. HAENDLER, W. L. PATTERSON and W. J. BERNARD: 'The Reaction of Fluorine with Zinc, Nickel, and Some of their Binary Compounds. Some Properties of Zinc and Nickel Fluorides.' *Jnl. Amer. Chemical Soc.*, 1952, vol. 74, June 20, pp. 3167-8.

Investigation of the reaction of fluorine with zinc, zinc oxide, zinc sulphide, nickel, nickel (II) oxide, nickel (III) oxide, and nickel sulphide. The crystal structures of the two fluorides were checked, and lattice constants were determined. Both are tetragonal: for nickel fluoride $a_o = 4 \cdot 6505 \pm 0 \cdot 0003$Å, $c_o = 3 \cdot 0837 \pm 0 \cdot 0005$Å. Densities were re-determined: for nickel fluoride $d = 4 \cdot 72 \pm 0 \cdot 05$ g./cc.

Effects of High Nickel Content of Soils on Crops

J. G. HUNTER and O. VERGNANO: 'Nickel Toxicity in Plants.' *Ann. Applied Biology*, 1952, vol. 39, June, pp. 279-84.

In certain small areas of Aberdeenshire crops have been found to be seriously affected by abnormally high nickel content of the soils. Specimens of soils showing such abnormality, and of plants grown on them under controlled conditions, have been examined at The Macaulay Institute for Soil Research, Aberdeen. This paper reports the major features of the investigation and the conclusions drawn. Much of the information given relates to oats, which are the most characteristically affected of the crops examined.

Effect of excess nickel, on growth and production of specific symptoms, is related to the nutrient status of the plants. Deleterious effects are more pronounced where the calcium, magnesium, nitrogen or potassium supply is low, or where phosphorus is high. The nickel content of plants grown on the soils examined was found to be apparently unrelated to the major-nutrient supply, although the harmful effect may be reduced when general nutrient supply is high.

For practical purposes the most satisfactory corrective treatment for nickel toxicity is the application of lime, together with nitrogenous and potassic fertilizers, application of phosphate being restricted as far as is consistent with the prevention of phosphorus deficiency. Where the pH of the soil is already high lime should not be applied, since manganese deficiency may be so produced. The effectiveness of calcium carbonate treatment is due to the reduction in availability of soil nickel resulting from the increase in soil pH.

ELECTRODEPOSITION AND OTHER COATING METHODS

Electrodeposition of Nickel with Insoluble Anodes

W. A. WESLEY, D. S. CARR and E. J. ROEHL: 'Nickel Plating with Insoluble Anodes.' Reprint of paper presented at 1951 Convention, Amer. Electroplaters' Soc., with discussion; 11 pp.

For abstract of paper see *Nickel Bulletin*, 1951, vol. 24, No. 11, p. 230. In discussion the authors referred to a paper published after their contribution was submitted to the A.E.S.: 'The Electrodeposition of Nickel in the Bores of Tubes Using Insoluble Anodes', by A. W. Hothersall and G. E. Gardam; see abstract in *Nickel Bulletin*, 1951, vol. 24, No. 5, pp. 99-100. Attention was also directed to U.S. Pat. 2,541,721, which covers the insoluble-anode procedure described by Wesley and his co-workers.

Electrodeposited Iron-Nickel-Cobalt Alloys for Glass-Metal Sealing

K. AOTANI: 'Electrodeposited Alloys.' *Jnl. Electrochemical Soc., Japan*, 1952, vol. 20, pp. 31-4: *Chemical Abstracts*, 1952, vol. 46, p. 4928.

'A description is given of a method to deposit electrolytically an alloy layer, composed of iron 55, nickel 30, cobalt 15, per cent. over a metal surface, for metal-to-glass bonding.'

S.A.E. Handbook: 1952 Edition

See abstract on p. 231.

NON-FERROUS ALLOYS

Diffusion Coefficients in the Nickel-Copper System

D. E. THOMAS and C. E. BIRCHENALL: 'Concentration Dependence of Diffusion Coefficients in Metallic Solid Solution.' *Jnl. of Metals*, 1952, vol. 4, Aug., *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 867-73: T.P. 3329E.

Study on the copper-palladium and copper-nickel systems.

'Diffusion coefficients in the Cu-Pd system have been determined as a function of temperature and concentration. The concentration dependence is slight in both extremes of concentration and strong at intermediate concentrations. The diffusion coefficient approaches the value of the self-diffusion coefficient of copper in dilute palladium solution.

'A re-determination of the dependence of the diffusion coefficients at the high copper end of the Cu-Ni system confirmed a strong dependence of the diffusion coefficient on composition in the relatively dilute solutions.

'Individual diffusion coefficients for copper and nickel atoms have been found by the use of markers at 89·9 atomic per cent. Cu. D_{Cu} is about 30 per cent. greater than D_{Ni} over the temperature range 923° to 1049°C.

'The deviation of the diffusion coefficient at infinite dilution from the self-diffusion coefficient of the solvent metal is generally greater, the greater the melting-point depression. Both factors also tend to become greater the more limited the solid solubility of the solute metal.'

S.A.E. Handbook: 1952 Edition

See abstract on p. 231.

Heat Conduction in Nickel-containing Materials at Low Temperatures

I. ESTERMANN and J. E. ZIMMERMAN: 'Heat Conduction in Alloys at Low Temperatures.' *Jnl. Applied Physics*, 1952, vol. 23, May, pp. 578-98.

The authors describe a method by which the thermal conductivity of relatively small samples can be measured in temperature regions obtainable by the use of liquid nitrogen, hydrogen and helium. Preliminary measurements on Monel, Inconel and nickel-chromium stainless steel gave Wiedemann-Franz ratios several times greater than the theoretical value of $2{\cdot}45 \times 10^{-8}$ watt-ohm/deg^2., the deviation being greater for annealed than for cold-worked specimens. This is interpreted by the authors in terms of appreciable lattice conduction of heat in these materials.

In view of these results, samples of a 90-10 copper-nickel alloy were prepared, having undergone varying amounts of cold work and having different grain sizes. Results obtained on the specimens were similar to those observed with Monel and Inconel, and confirm the hypothesis of lattice conduction. They also give a qualitative indication of the effectiveness of cold work in limiting lattice conduction of heat.

Properties of 90-10 Iron-containing Cupro-Nickel

See abstract on p. 247.

Iron-containing Cupro-Nickel: 'Kunifer 30'

See abstract on p. 248.

Thermal Conductivity of Nickel and Other Metals at Low Temperatures

See abstract on p. 232.

Copper-Nickel Alloy Castings

J. S. VANICK: 'Cupro-Nickel Castings.'*
Reprint from *Foundry*, 1952, vol. 80, Feb., pp. 100-5, 246-8, 250-3. Issued by International Nickel Co., Inc., 1952; 10 pp.
For abstract see *Nickel Bulletin*, 1952, vol. 25, No. 4, p. 101.

Nickel-Aluminium Bronze Castings: Production and Properties

V. DE PIERRE and R. C. WYNNE: 'Production of Aluminium-Nickel Bronze Sand Castings.' *Foundry*, 1952, vol. 80, July, pp. 94-7, 247-9.

Production variables which affect the quality of castings are discussed under the headings of (1) melting, (2) pouring, and (3) mould, conditions. Production

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practices used in the U.S. Naval Gun Factory, Washington, are described and the properties of the castings made are reviewed. This factory has produced aluminium-nickel-bronze sand castings ranging in weight from ¼ lb. to 300 lb., the average casting weighing 70-80 lb. Chemical compositions are controlled by strict specification and analysis, and mechanical properties are safeguarded by means of separately cast keel-type sand-cast test coupons poured from each melt. It is stated that mechanical-property requirements are met in 92 per cent. of the heats produced. The greatest difficulty is encountered in satisfying the 6 per cent. minimum elongation: low elongation values have been found to be associated with high aluminium content. Average composition of the Naval Gun Factory castings is: copper 82·80, aluminium 10·04, iron 3·92, nickel 3·18, manganese 0·17, tin less than 0·02, lead less than 0·02, per cent.

Staining of Nickel Silver after Pickling

A. L. SIMMONS: 'Staining of Copper Alloys after Pickling in Sulphuric Acid.' *Australian Jnl. Applied Science*, 1951, vol. 2, Dec., pp. 464-72.

In the manufacture of copper alloys in the form of annealed sheet and strip trouble is sometimes experienced from a more or less uniform dark staining of the finished material. The defect may appear at any stage up to about three months after completion of manufacture. It was thought possible that staining arose from insufficient attention to the composition of the baths used for final rinsing, after the pickling operation which is generally used for material which has been annealed. The laboratory investigation described in the present paper was carried out (at the Australian Government Ammunition Factory, Footscray, Victoria) to confirm this presumption and to determine the limits of acidity tolerable in final rinse baths used in commercial practice.

The programme consisted of three sections:—

(1) determination of effect of varying acid content of a synthetic rinse water, on onset and severity of staining in a range of copper alloys;
(2) determination of effect of the presence of copper sulphate in the solution used in (1), keeping the copper-to-acid ratio constant;
(3) comparison of the effects resulting from use of a typical pickling bath used commercially,* with those resulting from treatments (1) and (2).

The materials used were cap copper, gilding metal, cartridge brass, and nickel silvers containing 10, 18 and 20 per cent. nickel.

The results (recorded in full in the paper) lead to the following conclusions:—

With the three types of test solution used, rate of onset of staining is increased by (1) increased acid content in the final rinse solution, and (2) increased humidity during storage. Severity of staining (for any given period of storage) is increased by both (1) and (2) and, in addition, by increasing time of storage.

The presence of copper sulphate in a straight sulphuric-acid solution slightly lowers the acid concentration which can be tolerated without causing an unacceptable degree of staining. The maximum amount of acid (in straight acid solutions) which can be tolerated without causing appreciable staining after three months' storage under normal atmospheric conditions is of the order of 0·01 per cent. (For cap copper the concentration is slightly lower.) The use of a pickling bath containing chromium slightly accentuates the staining due to the acid, but the effect is not so marked as that due to increase in acid content alone. It is therefore concluded that the major cause of staining is presence of excessive acid in the final rinse water.

Differences in rate of onset and final severity of staining were observed among the materials tested: the order of *decreasing resistance* was found to be 18 and 20 per cent. nickel silvers; 10 per cent. nickel silver, cartridge brass and gilding metal; cap copper.

* Part-used bath in which chromium was present in both the oxidized (hexavalent) and reduced (tervalent) conditions.

Nickel-Manganese Alloys

T. SATO: 'Properties of Nickel-Manganese Alloys of Intermediate Composition.' *Jnl. Physical Soc., Japan*, 1951, vol. 6, pp. 223-7; *Chemical Abstracts*, 1952, vol. 46, p. 4982.

The electrical resistance of a nickel-manganese alloy containing 47 per cent. of manganese increases up to about 400°C. and is nearly constant from 400° to 500°C.; it decreases decidedly from 520° to 700°C., again becoming almost constant from 750° to 900°C., when the rate of heating and cooling is about 2°-3°C. per min. It is considered that the 50-50 per cent. alloy may be the Ni-Mn compound suggested by DOURDINE (*Chem. Abs.*, 1933, vol. 27, p. 693).

Aluminium Alloys containing Nickel: Reference Data

HIGH DUTY ALLOYS, LTD.: 'Hiduminium Technical Data.' Published by High Duty Alloys, Ltd., 1952; 125 pp.

A series of data sheets, charts, etc., giving a comprehensive survey of the composition, treatment and properties of the range of aluminium-base alloys made by this Company under the general designation 'Hiduminium'. Specifications to which the respective alloys conform are indicated. A number of the alloys referred to contain nickel as an integral constituent.

Nickel-Vanadium Alloys: Constitutional Study

W. B. PEARSON and W. HUME-ROTHERY: 'The Constitution and Structure of Nickel-Vanadium Alloys in the Region 0-60 At.-% Vanadium.' *Jnl. Inst. Metals*, 1951-52, vol. 80, pp. 641-52; *Monthly Jnl.*, Aug., 1952.

The equilibrium diagram of the nickel-vanadium system, within the range indicated, was investigated by thermal, microscopical, and X-ray methods.

It was found that there is a wide solid solution of vanadium in nickel, and that with increasing vanadium content the liquidus falls to a eutectic point at 51 at. per cent. vanadium, and 1202°C., at which temperature the liquid is in equilibrium with the α (nickel-base) solid solution of composition 42·7 at.

per cent. vanadium, and with a phase denoted σ, which has the same general type of crystal structure as the σ phase in iron-chromium alloys. At 1045°C. the α solid solution gives rise to a phase designated θ, which is a tetragonal superlattice based on the composition Ni_3V. The θ phase is of variable composition; its crystal structure was determined. In the region of 33·5 at. per cent. vanadium a second intermediate phase, designated δ, separates from the α solid solution. This is of almost fixed composition, and has a body-centred orthorhombic structure which may be regarded as the result of a monoclinic distortion of the face-centred cubic structure. The effects of composition on the lattice spacings of the α, θ and σ phases were studied, and the bearing of the results on the general theory of alloys is briefly discussed.

Constitution of the Chromium-Cobalt-Nickel-Molybdenum System

See abstract on p. 239.

Nickel-Silicon Alloys

N. F. LASHKO: 'The Nickel-Silicon Constitutional Diagram.' *Doklady Akad. Nauk, S.S.S.R.*, 1951, vol. 81, Dec., pp. 605-7.

Study of microstructure and lattice dimensions of alloys containing 2, 4 and 7 per cent. of silicon.

Intrinsic Magnetization in Nickel Alloys

See abstract on p. 237.

Spectrographic Analysis of Nickel-Cobalt Alloys

W. SEITH and A. KOTTMANN: 'Spectrographic Analysis of Nickel-Cobalt Alloys in the Range 0-100%.' *Spectrochimica Acta*, 1952, vol. 5, July, pp. 36-40.

It is shown that spectrographic analysis, which is usually restricted to determination of low concentrations of one element in another, may be extended to the study of the whole range of the nickel-cobalt system when the analysis is for the purpose of determining the diffusion coefficient of the solid metals. Samples of nickel and cobalt, in contact, are heated under conditions causing mutual diffusion, and layer after layer is cut from the treated mass for analysis.

Chemical Analysis of Nickel and Nickel Alloys: Recommended Procedures

INTERNATIONAL NICKEL CO., INC.: 'Methods for Chemical Analysis of Nickel and High-Nickel Alloys.' *Tech. Bull. T-36*,* 1952; 50 pp.

Full details of procedures currently used in the laboratories of The International Nickel Company, Inc., for determination of constituents occurring in various grades of nickel and high-nickel alloys (wrought and cast), filler materials used in welding, and weld-metal deposits made by all-nickel and high-nickel alloy electrodes. It is emphasized that, in general, the methods described are to be preferred to those published in the 1950 edition of 'A.S.T.M. Methods of Chemical Analysis of Metals'.

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Seam Welding of Thin Inconel Sheet

E. F. NIPPES and J. M. GERKEN: 'Seam Welding of 0·005-in. Inconel Sheet.' *Welding Jnl.*, 1952, vol. 31, Aug., Suppl. pp. 366-70.

Construction of a proton accelerator (a 'cosmotron'), at the Brookhaven National Laboratory, involved sealing the vacuum chambers with a skin of metal or plastic having desirable magnetic and dielectric properties. The purpose of the investigation reported in this paper was determination of seam-welding conditions and technique suitable for fabricating these skin sections from 0·005-in. thick Inconel sheet, 12 in. wide. The results reported showed that such sheet can be seam-welded, using a short 'on-off' cycle, provided that the movable-electrode assembly of the welding machine has a low inertia, to enable the electrode force to be maintained reasonably constant during the welding operation. Equipment was constructed to incorporate the feature of low moving head inertia and low friction.

Conditions were determined for welding 0·005-in. Inconel in both the annealed and ¾-hard conditions. A timing sequence of ½ cycle 'on', 4 cycles 'off', on a 60-cycle supply with 40 welds per inch, was arrived at for both types of sheet. A current of 1350-1425 amp. and an electrode force of 75 lb. are recommended for annealed sheet, and a current of 1250-1300 amp. and an electrode force of 95 lb. for the ¾-hard sheet.

Double seam welds made with the second seam at the extreme edge of the overlap were found to form an effective air seal with a ⅛-in. dia. neoprene gasket crossing it at right angles.

Monel-Clad Masts on Submarines

See abstract on p. 249.

NICKEL-IRON ALLOYS

Magnetostrictive Vibrational Characteristics of Nickel-Iron and Nickel-Copper Spheroids

J. S. KOUVELITES and L. W. MCKEEHAN: 'Magnetostrictive Vibration of Prolate Spheroids. Ni-Fe and Ni-Cu Alloys.' *Physical Rev.*, 1952, vol. 86, June 15, pp. 898-904.

The study of magnetic properties determined from the magnetostrictive vibrational behaviour of small ferromagnetic prolate spheroids (reported *ibid.*, 1951, vol. 84, p. 957) has been extended to investigation of a large number of nickel-iron and nickel-copper alloys, for which results are given in this paper.

The alloys were of the following compositions: nickel-iron containing 88, 84, 79, 68, 56 and 45 at. per cent. nickel, and nickel-copper containing 90, 84, 81 and 71 at. per cent. nickel.

The computed values for the saturation magnetostriction, the total change of Young's modulus with magnetization, and the initial permeability of plain-annealed* specimens of these materials, were inserted in two independent expressions (derived by Kersten) for the internal stress. Agreement between the two sets of values was found to be good. The nickel-iron

* Annealed in zero magnetic field.

alloys were also studied after annealing in a magnetic field, and a 68 per cent. nickel Permalloy, which is highly sensitive to strain, was investigated in the cold-worked, the baked, and the annealed conditions.

In general, changes of calculated internal stress with heat-treatment appeared to be consistent with corresponding variations of properties such as initial permeability. Values for domain size, determined from computed dissipation factors and internal stresses, were found to agree well with previous measurements of Barkhausen discontinuities. Consideration of curves showing relative change of Young's modulus *vs.* relative magnetization, supported by observations made in earlier work, lead to the conclusion that these curves should be similar for all plain-annealed* face-centred cubic structures at room temperature.

Intrinsic Magnetization in Nickel Alloys

W. J. CARR: 'Intrinsic Magnetization in Alloys.' *Physical Rev.*, 1952, vol. 85, Feb. 15, pp. 590-4.

The intrinsic magnetization of alloys among the iron transition group of metals is discussed. Phenomena in nickel-manganese, cobalt-iron, nickel-iron, iron-chromium and iron-vanadium alloys are used as a basis for the conclusions drawn.

Ferromagnetic Resonance in Nickel Ferrites

D. W. HEALEY: 'Ferromagnetic Resonance in Nickel Ferrite as a Function of Temperature.' *Physical Rev.*, 1952, vol. 86, June 15, pp. 1009-13.

Study, on $NiOFe_2O_3$, over the temperature range $-195°$ to $+588°$C., of the line width of the resonance curve, the variation of the spectroscopic splitting factor, g, and the magnetic anisotropy constants, K_1 and K_2. Line width decreases with rise of temperature, the g value remains essentially constant, and the two anisotropy constants show different sign behaviour over the temperature range.

High Magnetic Permeability of Permalloy

S. CHIKAZUMI: 'The Origin of High Permeability in Permalloy.' *Physical Rev.*, 1952, vol. 85, Mar. 1, pp. 918-19.

Report of investigation of properties of Permalloy nickel-iron alloys, as associated with formation of superlattice at 490°C. An explanation in terms of 'directional order' is advanced. Domain patterns observed on Ni_3Fe crystals are illustrated.

Influence of Heat-Treatment on Magnetic Viscosity of Nickel-containing Permanent-Magnet Alloys

R. STREET, J. C. WOOLLEY and P. B. SMITH: 'The Influence of Heat Treatment on Magnetic Viscosity in Permanent Magnet Alloys.' *Proc. Physical Soc., Section B*, 1952, vol. 65, June 1, pp. 461-2.

Widely differing forms of heat-treatment may result in production of specimens having the same coercive force, as, for example, in Alnico, in which the same coercive force is achieved by a relatively slow quench from 1250°C. or by a rapid (cold water) quench followed by annealing at 700°C. Magnetic viscosity in an Alnico-type alloy is, on the other hand, a unique function of the previous heat-treatment. The phenomenon is illustrated in this note by curves showing observations made on Alnico specimens which had been subjected to different treatments:—(1) cooled from 1250°C. at different rates, varying from water-quenching to cooling the specimen at the natural rate of cooling of the furnace with the current switched off, and (2) cold-water quenched, followed by successive annealing at 700°C. for times varying from 5 minutes to 140 hours.

Recovery of Nickel and Other Metals from Permanent-Magnet Alloys

A. H. SHERMAN and M. PESSES: 'Alnico Recovery Process Salvages Valuable Nickel, Cobalt.' *Iron Age*, 1952, vol. 170, July 3, pp. 115-19: see also comments, *ibid.*, Aug. 21, p. 9.

This article describes a method (still in the pilot-plant stage, but scheduled for industrial use within the next few months) by which nickel, cobalt and copper are salvaged from waste residues produced in manufacture of permanent magnets of Alnico and related types. The slags and residues arising consist of three totally different types of material: (1) Alnico skimmings, made up of metallic particles encased in a highly refractory alumina slag: (2) a by-product material occurring in final grinding, which consists of fine metallic particles contaminated with oil and abrasives, and (3) similar to (2), except that water is present instead of oil. The three separate types of dross require different preliminary processing and special treatment prior to being run through a magnetic separator, after which the materials are re-blended to proportions found final optimum for treatment. Aluminium is added, as deoxidizer, also silica and sodium silicate, to produce a marketable slag. The mix is charged into a 4000-lb. rotary furnace, and brought to a temperature of 3000°-3300°F. (1650°-1815°C.). After 6 hours in the furnace the first aluminium addition is made. This reacts with the oxides of nickel, cobalt and iron present in the melt, and causes an aluminothermic reaction, which reduces the oxides. When this reaction is complete, an excess of aluminium is added, to bring the material up to specification requirements. Immediately prior to pouring off the heat of metal sufficient iron oxide is added to lower the carbon and silicon contents of the bath to the required values. The alloy is then poured into shot or ingot form, for use by magnet makers. The method has the dual advantage of salvaging strategic metals, and of providing an additional source of supply at an economic price.

Spectral Emissivity of Nickel and Nickel-Iron Alloys

See abstract on p. 232.

Electrodeposited Iron-Nickel-Cobalt Alloys for Glass-Metal Sealing

See abstract on p. 234.

CAST IRON

Iron Castings: Glossary of Terms Used

INTERNATIONAL NICKEL CO., INC.: 'Glossary of Terms for Producers and Users of Iron Castings.'* *Published by the Company*, July, 1952; 32 pp.

The major part of the publication comprises a *glossary* of over 160 terms commonly used in the foundry and in relation to the properties of cast iron. It also contains notes on the important changes which have taken place in cast iron during recent years, e.g., higher strength, improved machinability, better resistance to wear and to corrosion, etc. The rôle of alloying additions in promoting such improvement is emphasized, with special reference to benefits derived from the use of varying percentages of nickel. The essential compositions and characteristics of low-alloy engineering irons, the five grades of Ni-Resist, Ni-Hard and Ductile Cast Iron (spheroidal-graphite iron) are outlined.

Ni-Hard Balls for Grinding Paint

K. A. DELONGE: 'Paint Grinding Balls made of Improved Alloy Cast Iron.' *Reprint from Paint and Varnish Production*, Sept., 1950.

Issued by International Nickel Co., Inc.; 2 pp.

This short publication records the properties of Ni-Hard (martensitic white cast iron containing nickel 4·0-4·75, chromium 1·4-3·5, per cent.), which is characterized by high hardness and outstanding resistance to abrasion.

Investigation of the service behaviour of Ni-Hard balls ($\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$ and 1-in. dia.) for paint grinding and mixing has shown that they are particularly suitable for this purpose and that marked economies may be effected by substitution of Ni-Hard balls for balls of hardened steel. The moderate price of the alloy cast iron balls offers an immediate advantage, by reducing costs of grinding media, and a second, and more important, gain is that the martensitic white iron ball, due to its very low rate of wear, permits grinding of pastel pigments, for which grinding with porcelain balls or flint pebbles was previously necessary, in order to prevent discolouration. Consideration is being given to using the alloy iron for mill liners as well as balls, in order to achieve minimum discolouration.

CONSTRUCTIONAL STEELS

U.S. Specifications for Nickel-Alloy Steel Castings

'Summary of Standard Specifications for Steel Castings.' *Materials and Methods*, 1952, vol. 36, July, pp. 121, 123.

Tabular summary of mechanical-property limits, composition, and other requirements for low- and medium-alloy steel castings, laid down in standard specifications issued by U.S. Governmental and civilian standardizing agencies.

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S.A.E. Handbook: 1952 Edition

See abstract on p. 231.

Sub-Zero Properties of Metals and Alloys

See abstract on p. 230.

Spectrophotometric Determination of Nickel in Steel

See abstract on p. 232.

HEAT- AND CORROSION-RESISTING ALLOYS

Constitution of Nickel-Chromium-Iron Alloys

A. J. COOK and B. R. BROWN: 'The Constitution of Iron-Nickel-Chromium Alloys at 550°-800°C.' *Jnl. Iron and Steel Inst.*, 1952, vol. 171, Aug., pp. 345-53.

A considerable amount of study has recently been carried out on the range of composition in which nickel-chromium-iron alloys are liable to formation, at service temperatures, of sigma phase, and associated deterioration of mechanical properties. The use of such alloys for gas-turbine components has accentuated the need for accurate determination of the constitution of the system at temperatures of 550°-800°C.

The composition range over which sigma is found at 650° and 800°C. in alloys containing up to about 60 per cent. of nickel and up to 50 per cent. of chromium was investigated earlier at the National Physical Laboratory (*ibid.*, 1949, vol. 162, pp. 325-36): the present paper deals mainly with study of the constitution of some of the same alloys at 550°C. Results are reported of metallographic and X-ray examination of alloys containing nickel 0-40, chromium 0-35, per cent. The alloys were heat-treated for periods up to 700 days at 550°C., but due to the persistence of the metastable alpha phase in those containing more than 20 per cent. of nickel the phase boundaries beyond this limit have not been definitely fixed. It is concluded from the slow rate of change observed in the alloys studied at 550°C. that cases in which the austenite loses more chromium than is indicated by the diagram for equilibrium at 550°C. will be rare in practice.

Results recorded in the earlier work describing equilibrium at 650° and 800°C. (*loc. cit.*) showed certain discrepancies between the X-ray and microscopic observations, but additional work reported in the present paper has made it possible to fix certain details of the constitution at those temperatures with greater certainty.

Nickel-Chromium-Iron Constitutional Diagrams: Reference Data

'Ni-Cr-Fe Ternary Diagrams.' *Metal Progress*, 1952, vol. 62, Aug., p. 96B: Data Sheet.

Isothermal diagrams showing phase boundaries at various temperatures, adapted from publications on original research, to which reference is given. Diagram showing stable and metastable phases in quenched alloys containing about 0·10 per cent. carbon.

Constitution of the Chromium-Cobalt-Nickel-Molybdenum System

S. P. RIDEOUT and P. A. BECK: 'Survey of Portions of the Chromium-Cobalt-Nickel-Molybdenum Quaternary System at 1200°C.' *Nat. Advisory Committee for Aeronautics, Tech. Note* 2683, Apr., 1952; 81 pp.

This report covers part of an extensive investigation in progress at the University of Notre Dame, on phase relationships in alloy systems involving chromium, cobalt, nickel, iron, and molybdenum, these series being most important in connexion with high-temperature materials.

Since the face-centred cubic (alpha) solid solutions form the matrix of almost all practically useful high-temperature alloys, the solid-solubility limits of the quaternary alpha phase were determined up to 20 per cent. molybdenum. The component ternary systems cobalt-nickel-molybdenum, chromium-cobalt-molybdenum, and chromium-nickel-molybdenum were also studied, the survey of these systems being restricted to determination of the boundaries of the face-centred cubic (alpha) solid solutions and of the phases co-existing with alpha at 1200°C. The report of the observations made on each of the above alloy groups is preceded by a detailed description of the metallographic characteristics of the various phases identified in one or more of the systems. The following phases are described: alpha, epsilon, sigma, delta, mu[1], P[2], R[3] and impurity phases.

The results are embodied in a series of diagrams, and the individual observations on which these diagrams are based are recorded in great detail, with comparison of data obtained by microscopical and by X-ray methods. *Inter alia*, much information is given on etching solutions and procedure, which it was found necessary to vary within wide limits according to the composition of the alloys.

S.A.E. Handbook: 1952 Edition

See abstract on p. 231.

Nimonic Alloys: Properties and Uses

HENRY WIGGIN AND CO., LTD.: 'The Nimonic Alloys.' *Publn.* 459A, 1952; 42 pp.

This publication is a revised and amplified edition of No. 459, which was issued in 1951; see *Nickel Bulletin*, 1951, vol. 24, No. 12, p. 263. It contains additional data on Nimonic 80A, and gives preliminary information on three new alloys: Nimonic 95 (a modification of Nimonic 90, giving superior creep properties in the highest temperature ranges), and Nimonic DS and DT, two grades of 37-18-2 nickel-chromium-silicon-iron alloy suitable for various forms of high-temperature service.

(1) Mu: solid solutions based on the intermediate cobalt-molybdenum epsilon phase were re-named mu, to avoid contradictions in nomenclature.

(2) P phase: discovered in the 1200°C. isothermal section of the chromium-nickel-molybdenum system: closely similar to the sigma phase: crystal structure not determined.

(3) R phase: observed in the 1200°C. isothermal section of the chromium-cobalt-molybdenum system; crystal structure not determined.

Creep Testing of Nimonic Alloys

C. W. WEAVER: 'Specification Creep Testing of Nimonic Alloys for Gas Turbines.' *Rev. de Métallurgie*, 1952, vol. 49, July, pp. 511-22; disc., pp. 522-3.

Reprint of paper presented at Journées d'Automne de la Société Française de Métallurgie, Oct. 1951. The author describes the equipment and procedure used for creep-testing the nickel-chromium-base alloys developed by The Mond Nickel Company for components of gas turbines.

Abnormal Grain Growth in Jet-Engine Alloys

A. I. RUSH, J. W. FREEMAN and A. E. WHITE: 'Abnormal Grain Growth in S-816 Alloy.' *Nat. Advisory Committee for Aeronautics, Tech. Note* 2678, Apr., 1952; 30 pp.

The occurrence of abnormally large grain in blades for gas turbines, particularly when segregated in certain portions of steel blades, is associated with undesirable service characteristics. The phenomenon is a generally recurring problem, and as such is being fundamentally investigated by the National Advisory Committee for Aeronautics. The report now issued covers progress to date, and is confined to results obtained in experiments designed to induce abnormal grain growth in bar stock under controlled conditions, using S-816 alloy (carbon 0·38, manganese 1·28, silicon 0·23, phosphorus 0·011, sulphur 0·019, chromium 19·51, nickel 19·91, molybdenum 3·82, tungsten 4·15, iron 3·65, niobium 3·84, per cent., cobalt balance). In general, the conditions used were intended to simulate those involved in forging gas-turbine blades of S-816.

The conclusions drawn from the work reported are as under:—

'Abnormal grain growth can be induced by water-quenching, and in many cases by air-cooling, bar stock from 2150° or 2300°F. (1176° or 1260°C.). Such temperature cycling definitely makes the alloy susceptible to grain growth during final solution treatments. The critical deformation during rolling for grain growth was between 0 and 2 per cent. and was independent of the temperature of deformation.

'Repeated critical deformations between reheats to 2150°F. (1175°C.) induced much larger grains during solution treatment than a single critical deformation.

'The prevention of susceptibility to abnormal grain growth during solution treatment apparently requires that the material be deformed more than 2 per cent. and that cooling rates be kept slow.

'Abnormal grain growth can be induced under certain conditions when working and solution-treatment temperatures are restricted to 2150°F. (1175°C.).

'The development of susceptibility to grain growth by temperature cycling, and by critical deformation, is sensitive to prior history. It is expected that this will be important to those cases where abnormal grain growth is encountered when temperatures are restricted to 2150°F. (1175°C.) during solution treatment and important only to the details of grain growth when solution-treated at 2300°F. (1260°C.).

'Because prior history does influence grain-growth tendencies and because a number of other variables

have received limited attention, the conclusions require further investigation before their generality should be accepted.'

Hastelloy X: A New Alloy for High-Temperature Service

'New High-Temperature Alloy.' *Materials and Methods*, 1952, vol. 36, Aug., pp. 98-9.

This new alloy, announced by Haynes Stellite Company, is of a composition designed to effect saving in strategic elements: it is intended to replace cobalt- and niobium-bearing materials such as Multimet, and to be used, in some applications, in place of alloys of higher nickel content. It is noted that the iron content is sufficiently large to permit use of ferrochromium instead of the pure chromium essential for the production of some of the high-temperature alloys. The table below gives composition and properties claimed as typical.

The preferred heat-treatment for Hastelloy X sheet is annealing at 2130°-2150°F. (1165°-1175°C.) for 10 minutes, followed by rapid air-cooling. Prolonged exposure at elevated temperatures causes some age-hardening and loss of ductility, but under these conditions Hastelloy X does not become so hard and brittle as Hastelloy C, and it is considered that age-hardening will not be a serious problem in most applications.

Complete data are not yet available on elevated-temperature properties, but those already determined are compared, in the table, with corresponding information for Multimet, on which considerable work has been done. Although Multimet shows creep properties superior to those of the new alloy, Hastelloy X sheet has passed the *minimum* creep-rupture requirements established for Multimet. Preliminary test results indicate good resistance to oxidation.

It is suggested that Hastelloy X should be suitable for sheet-metal components in jet engines, cabin heaters, jet-aircraft tail cones and collector-ring parts, and in the metallurgical and process industries. It shows suitability for precision investment casting, and in this connexion is under investigation for use in aircraft nozzle vanes.

Comparison of Wrought Hastelloy X and Multimet (N-155) Alloys

Alloy	Nominal Composition	Temperature		Short-Time Tensile Properties			Creep-Rupture Properties		
				U.T.S.	Yield Strength 0·2% Offset	Elongation % on 2 in.	Stress	Rupture Life, Hours	Elongation % on 2 in.
	%	°F.	°C.	p.s.i.	p.s.i.		p.s.i.		
Hastelloy X	C 0·15 max.	Room		116,000	57,000	44·5	—	—	—
	Cr 22	1200	648	—	—	38	15,000	500*	0·285
	Mo 9						45,000	90	20·0
	Ni 45	1350	734	68,000		31	—	—	—
		1500	815	48,000		37	18,000	—	35·0
		1650	898	31,000		41	—	30	—
		1800	981	20,000		41	—	—	—
Multimet N-155	C 0·08-0·16	Room		116,000	57,000	43	—	—	—
	Cr 20-22·5	1200	648	—		35	15,000	500*	0·175
	Mo 2·5-3·5						45,000	175	11·0
	Co 18·5-21	1350	734	55,000		39	—	—	—
	W 2-3	1500	815	37,000		39	18,000	80	28·0
	Ni 19-21	1650	898	27,000		40	—	—	—
	N 0·10-0·20	1800	981	17,000		37	—	—	—
	Nb+Ta 0·75-1·25 Fe Rem.								

* Tests discontinued.

Effect of Periodic Overstressing on Creep of Nickel-containing High-Temperature Alloys

G. J. GUARNIERI and L. A. YERKOVICH: 'The Influence of Periodic Overstressing on the Creep Properties of Several Heat-Resistant Alloys.' *Amer. Soc. Testing Materials, Preprint* 72, June, 1952; 13 pp.

In aircraft turbojet service at least two operating conditions may alter the life expectancy of a high-temperature material, as based on laboratory or other tests made under normal or average conditions. These are (1) overheating of engine parts, and (2) abnormal loading of components at elevated temperatures, such as might be encountered in unusual acceleration demands. It is with (2) that this paper is concerned: it deals with technique for overload creep testing, and the effects of variables in overstressing conditions on the creep and rupture properties of three typical materials normally used for components operating in various temperature ranges. An annealed low-carbon N-155 Multimet sheet material of 0·055 in. thickness was used for overload testing at 1500° and 1800°F. (815° and 980°C.); precision-cast H.S.21 cobalt-base alloy specimens were similarly studied at 1500°F. (815°C.); annealed Type 347 sheet, 0·050 in. thick, was chosen to provide data representative for the 1200°-1500°F. (650°-815°C.) range. Results are correlated into design charts relating variables of stress, time, temperature, ratio of overstress to normal stress, and time percentage of application of overstress. It was observed that application of overloads for even relatively small percentages of total test time produced rapid fall in creep and rupture life. The authors also explored the potential value of a method for calculating overstress characteristics of materials from static load creep-test data. Acceptable agreement was obtained with experimental results.

Sigma Formation in 18-8-Mo-Ti Steel: Associated Phase Changes

K. W. J. BOWEN and T. P. HOAR: 'Phase Changes Associated with Sigma Formation in 18-8-3-1 Chromium-Nickel-Molybdenum-Titanium Steel.' *Proc. 1st World Metallurgical Congress*, 1951, pp. 695-706.
Published by Amer. Soc. Metals, 1952.

Formation of sigma phase from ferrite has been described by various investigators, in connexion with studies of alloys of iron, chromium and nickel, with or without additions of small amounts of other elements. In this paper the relevant literature is briefly surveyed, as an introduction to a report of results obtained by quantitative metallographic and magnetic phase analysis, and by density determinations, designed to elucidate the manner in which ferrite transforms to sigma and to austenite in an 18-8 steel containing molybdenum (3·40 per cent.) and titanium (0·47 per cent.). This type of steel, after heating at 1150°C. and water-quenching, consists of about equal proportions of ferrite and austenite: the effect of re-heating at 850°, 800° and 750°C. was investigated.

Re-heating at 850°C. causes, in a few minutes, formation of a maximum of about 14 vol. per cent. of sigma from ferrite: the remaining ferrite then slowly transforms to austenite over a period of many hours. Sigma formation is accompanied by a marked increase in density; austenite formation is associated with a less strongly marked increase. In the quenched or air-cooled steel austenite which is retained after sufficiently long heating at 750° or 800°C. partly transforms by diffusionless change to ferrite at room temperature; austenite similarly formed at 850°C. is stable at room temperature if the steel is water-quenched, but partially transforms when the steel is immersed in liquid nitrogen.

High-Temperature Properties of Titanium-Stabilized Stainless Steel

J. W. FREEMAN, G. F. COMSTOCK and A. E. WHITE: 'Rupture and Creep Characteristics of Titanium-Stabilized Stainless Steel at 1100° to 1300°F.'
Trans. Amer. Soc. Mechanical Engineers, 1952, vol.74, July, pp. 793-801; disc., p. 801.

The authors draw attention to the relatively small amount of data which has hitherto been published on rupture and creep characteristics of titanium-stabilized steel. The main facts established by earlier publications are briefly summarized as a preliminary to report of results of an investigation planned to determine the influence, on high-temperature properties, of heat-treatment and of variations in the ratio of titanium to carbon, within the ranges usual in A.I.S.I. 321 steel. Bar stock from commercial heats, variously heat-treated, was tested (rupture and creep) at 1100°, 1200° and 1300°F. (593°, 648° and 704°C.). The main investigation was based on specimens air-cooled after solution treatment: a few tests were made on water-quenched specimens, to investigate the possibility that cooling rate might be a factor affecting creep properties. A minor study of the effect of aluminium was made on split heats from a laboratory induction furnace.

Subsequent to testing, many of the specimens were examined microscopically, to determine microstructural changes which had occurred during test: alteration of room-temperature properties after high-temperature test was also determined.

From the results obtained in the above tests, and a comparison of the properties of the 18-8-Ti with 18-8-Nb and straight 18-8 steels (full details of which are given) the following conclusions are drawn:—

'(1) A wide range in either creep or rupture strengths is possible for all three grades of steel. Under present applicable specifications there would seem to be little to differentiate between the 18-8+Ti and 18-8+Nb steel. The strengths of 18-8+Ti and 18-8+Nb tend to average higher than 18-8, although some values are lower than those for 18-8.

'(2) The low strengths for 18-8+Ti and 18-8+Nb steels at temperatures of 1200°F. (648°C.) and above have been associated with fine grain size and the development of sigma phase, the high strengths with solution treatments which resulted in coarsening of the grains. In all probability, if tests were made with higher solution temperatures than those reported, values would be obtained for 18-8+Ti as high as have been reported for 18-8+Nb steel.

'(3) Study of the individual tests which have been

reported for both 18-8+Ti and 18-8+Nb steels indicates that the properties obtained are not predictable from heat-treatment or grain size alone, at least where grain sizes are finer than No. 4. Considerable study of the phenomena suggests that the properties are certainly affected by hot-working conditions and probably by melting practice. Because a given grain size can be obtained by various prior treatments, it is probable that specification of grain size, Ti/C ratio, and heat-treatments would not entirely insure closely reproducible properties.

'(4) Some of the data reported in the literature indicate that heat-treatment at 1900° to 2000°F. (1035° to 1095°C.) produces the best all-round properties in 18-8-Ti or 18-8-Nb steel. Data obtained by the authors show that properties on the low side of the range can result from heat-treating 18-8+Ti steel at 1900°F. (1035°C.). Because the low properties are associated with sigma-phase formation and because 18-8+Nb is also susceptible to the same reaction, it would seem possible that 18-8+Nb might also have low strengths with such treatment.

'(5) Although the fine-grained 18-8+Ti and 18-8+Nb steels have quite good comparative strengths at 1100°F. (595°C.), one exception was found in the 0·00001 per cent. per hour creep strength reported for an 18-8+Ti steel. Thus it does not appear safe to generalize that a fine-grained material will always have good comparative strength at 1100°F.

'(6) In general, 18-8 steel data do not show as high or as low values as have been reported for 18-8+Ti or 18-8+Nb steel. In so far as the authors have been able to determine, 18-8 steel is not subject to the sigma-phase reaction. The somewhat narrower range for the unstabilized steel is probably associated with the absence of the sigma-phase reaction.

'(7) The data in the literature seem generally to bear out the findings of the present tests that strength at high temperatures in 18-8+Ti steel is a function of Ti/C ratio. A steel having a 3·8 Ti/C ratio had high strength, and a 10·9 Ti/C ratio steel had low strength.'

Coal-Burning Locomotive Gas Turbine

J. I. YELLOTT: 'L.D.C. Gas Turbine Runs on Coal.' *Power Engineering*, 1952, vol. 56, May, pp. 56-9.

The article gives a description of the (U.S.) Locomotive Development Committee's full-size locomotive gas turbine, which has been under test operation, burning bituminous coal, for 178 hours. Inspection at the end of that period showed clean turbine rotor blades, and only one small spot of erosion on one cylinder blade.

Performance data are given, also particulars of the materials from which the major components of the turbine are constructed. These include cylinder blading and rotor blades of S-590, the use of 19-9 DL for the turbine casing, and of Inconel and Type 347 stainless steel for combustors, louvres and internal components of the fly-ash separator. Tees, elbows and shell of the separator were made from Inconel X, since this was the strongest material which could be formed into the required shapes.

Hot Machining of High-Alloy Materials

A. A. CAMINADA: 'Hot Machining Methods for Difficult-to-Machine Metals.' *Materials and Methods*, 1952, vol. 36, July, pp. 98-100.

Interest in hot-machining methods has been much stimulated in recent years by problems encountered in machining high-temperature alloys and other refractory materials. Several techniques have been developed, each of them having its own advantages and limitations. The features of the respective processes are critically discussed in this article, in mutual relation, and in relation to cold-machining procedure.

Hot-machining procedures are basically of two types: in one the entire piece is heated, whereas in the other only the spot immediately in front of the tool is preheated, and this area is removed as quickly as possible. These two basic methods have been applied chiefly in the following ways: (1) by machining the work while it is still hot from other manufacturing processes; (2) by pre-heating the work and machining before it cools, meanwhile insulating the holding device to prevent excessive loss of heat; (3) by heating the workpiece on the machine immediately ahead of the tool by induction, with a flame, or with an electric arc; (4) by surface heating the work-piece in advance of the tool. The first procedure is used in steel mills, for example, for hot sawing of steel billets: the others have been used for machining of parts in the shop. Experience gained in the use of the respective methods is described by the author, and the discussion is illustrated by diagrams showing results obtainable by hot machining of stainless nickel-chromium steel and other materials. Although investigation of the potential usefulness of hot machining is not yet complete, it is already clear that the method has advantages in handling materials which give difficulty in cold machining, that a good finish is obtained on hot-machined work, and that for some materials the procedure is an economic proposition.

Nickel-Chromium-base Alloy for Brazing Stainless and Heat-Resisting Materials

R. L. PEASLEE and W. M. BOAM: 'Design Properties of Brazed Joints for High-Temperature Applications.' *Welding Jnl.*, 1952, vol. 31, Aug., pp. 651-62.

This paper, presented to the American Welding Society in 1951, describes a brazing technique developed by Curtiss-Wright Corporation, employing Nicrobraz* (formerly Colmonoy No. 6) as the brazing material and operating with a dry-hydrogen atmosphere. Tests to determine the suitability of various materials for brazing by this process are recorded, covering experimental work on S-590 and N-155 Multimet, as typical of high-temperature alloys, and Types 347 and 431 as representative, respectively, of the austenitic and martensitic types of stainless steels. Design of joint, mode of application of the brazing alloy to the joint, and other aspects of technique are considered, and the properties of brazed joints in the various materials are recorded, with particular refer-

* Carbon 0·45, silicon 4·05, chromium 15, boron 3·75, iron 4·0, per cent., nickel balance.

ence to their behaviour at elevated tempera ures. Oxidation-resisting characteristics of the joints are included in the discussion. Comparisons are made throughout the report between Nicrobraz-brazed joints and joints brazed with copper and silver-manganese brazing materials. The final section of the paper gives some account of dry-hydrogen brazing of actual turbine components.

The authors make the following summary of conclusions drawn from their experiments and experience:

'Nicrobraz stainless brazing alloy, when used with the appropriate base metal and brazed (following proper techniques) in a dry-hydrogen atmosphere, has satisfactory physical properties and oxidation resistance for high temperature applications through 2000°F. (1095°C.).

'Stainless steel parts are readily and economically fabricated by brazing with the Nicrobraz stainless alloy without scaling, appreciable distortion, or internal stress.

'Oxygen-free copper and 85 per cent. silver—15 per cent. manganese, as brazing alloys, do not have suitable physical properties or oxidation-resistance for application at temperatures over 900°F. (480°C.).

'The quantity of the Nicrobraz alloy must be critically controlled because base-metal solution at the brazing temperature varies directly with the weight of stainless brazing alloy used and the time at heat. The weight of alloy is the more important variable.

'Metals having high quantities of aluminium or titanium as alloying elements are difficult to braze in a dry-hydrogen atmosphere.

'Acrylic resins are a satisfactory binder for holding the powdered stainless brazing alloy in place before and during the brazing operation. The binder is best used in small quantities and does not interfere with the dry-hydrogen atmosphere. Plastic bonded strip and wire are also important methods of applying the brazing alloy."

Hastelloy Alloys : Reference Data

E. D. WEISERT: 'Hastelloy Alloy C.' *Chemical Engineering*, 1952, vol. 59, June, pp. 297-8, 300, 302, 304-6, 308-10, 312.

Charts giving qualitative data on resistance to 150 corrosive reagents, and typical mechanical properties, of the nickel-base alloy containing molybdenum 16-18, chromium 15·5-17·5, iron 4·5-7·0, tungsten 3·75-4·75, carbon 0·15 max., manganese 1·0 max., silicon 1·0 max., phosphorus 0·04 max., sulphur 0·03 max., per cent., nickel balance. This alloy retains, to a large degree, the resistance to non-oxidizing corrosives characteristic of nickel-molybdenum alloys, and the addition of chromium imparts general resistance to oxidizing conditions. The material is being made in various wrought forms, and also as sand or precision-investment castings.

'Hastelloy Alloy B.' *ibid.*, July, pp. 314-28 (even numbers only).

This article gives similar information for the B alloy, for which the typical composition is cited as: molybdenum 26-30, iron 4-7, chromium 1·0 max., silicon 1·0 max., carbon 0·12 max., manganese 1·0 max., per cent., nickel balance. Data on behaviour in contact with 190 corrosives are charted and mechanical- and physical-property information is given. Hastelloy B is particularly well suited for handling hydrochloric acid at all concentrations and temperatures, and also for use in contact with wet hydrogen-chloride gas.

Compositions, Properties, Fabrication and Uses of Stainless Steels

B. T. LANPHIER: 'Factors in Selecting Stainless Steels, to Reduce Costs, Improve Performance, and Conserve Critical Alloying Elements.' *Machine Design*, 1952, vol. 24, July, pp. 112-28.

A detailed practical discussion of the characteristics of the various grades of chromium and nickel-chromium stainless steels, as an aid to the designer in selection of the materials most suitable and most economic for specific applications, with particular reference to current requirements for conservation of alloy elements. Individual examples of substitutions which have been made in the interests of economy, without loss of efficiency, are given.

Heat Conduction in Nickel-containing Materials at Low Temperatures

See abstract on p. 234.

Sub-Zero Properties of Metals and Alloys

See abstract on p. 230.

Shell Moulding of Nickel-Chromium Stainless Steel

G. F. SULLIVAN: 'Shell Molded Stainless Valves and Fittings now in Production.' *Iron Age*, 1952, vol. 169, June 25, pp. 112-16.

This article describes shell-moulding practice in the plant of The Cooper Alloy Foundry Company, at Hillside, N.J., where this process for production of stainless steel castings is being actively developed. To date the method has been used only for valves and fittings, but the Company is anticipating that other types of castings will be produced in the near future. Most of the valves or fittings are cast in Type 304 or 316 stainless steel, and it is stated that metal yield in these steels has been increased, by shell moulding, by 20-35 per cent. over that obtained with regular green-sand practice. This, in turn, has resulted in faster production of more castings per ton of metal melted and poured, and less scrap is generated. Improvement in the cast surfaces secured by shell-moulding reduces cleaning time to a minimum, and a product of better surface quality is ensured. Handling, storage and space considerations are also in favour of the shell-moulding process.

The Cooper Foundry uses the regular type of resins, in a mixture of 8 per cent. resin, 87 per cent. sand, with a balance (5 per cent.) of −200 mesh iron oxide, the addition of which has been found to improve the surface of the castings. Oil-bonded sand cores, washed in a mixture of zircon flour, Bentonite and alcohol, are employed with the shells.

In this article a well-illustrated step-by-step description is given of the sequence of operations used in the shell moulding of typical castings.

Cold-Forming of Stainless Steels

K. ROSE: 'Cold-Forming Stainless Steel Parts.' *Materials and Methods*, 1952, vol. 36, July, pp. 101-16; *Materials and Methods Manual*, No. 84.

Practical discussion, in relation to processing of austenitic nickel - chromium steels and straight - chromium grades. Consideration of factors influencing selection of stainless steels for various types of cold-forming operation; cold-forming properties of the respective grades; cold-forming methods (drawing; blanking, shearing and punching; perforating; press- or brake forming; cold heading; spinning; draw-rolling); processing materials (tools and die materials, lubricants), and annealing procedures; cleaning and polishing methods.

'Sol-a-Die' Process for Forming Stainless Steel

'Sheet Metal Forming Process.' *Engineer*, 1952, vol. 194, Aug. 1, p. 156.

Development, by Solar Aircraft Company, of the 'Sol-A-Die' method of forming sheet metal by stage dies grew out of attempts to overcome the difficulties encountered in drawing 18-8 stainless steel into the intricate shapes required by exhaust-manifold design. The process is claimed to cut the cost of tooling, speed output, eliminate tearing, breaking and thinning in the forming of sheet-metal shapes, and reduce scrap. The first British licence for use of the process has recently been granted to Rolls-Royce, Ltd., of Derby.

Resistance of Copper- and Molybdenum-containing Nickel-Chromium Steels to Acid Corrosion

H. THIELSCH and W. E. PRATT: 'Highly Alloyed Stainless has More Acid Resistance.' *Iron Age*, 1952, vol. 170, July 10, pp. 135-9.

The article deals with the advantages of austenitic chromium-nickel steels containing varying combinations of molybdenum and copper, as materials for handling sulphuric acid. Typical compositions are listed, with details of American proprietary trade names and makers. Test results are recorded to demonstrate the corrosion-resisting qualities of the steels under varying conditions of concentration and temperature.

Among the points made in the discussion are:—

These highly alloyed steels are primarily austenitic, but other phases also appear. In addition to carbide precipitation and formation of sigma phase, exposure in certain temperature ranges may cause formation of copper-rich phases, which under some conditions of exposure (e.g., hot, strong sulphuric-acid solutions) may seriously increase corrosive attack. Other structural phases may further accentuate rates of corrosion in hot concentrated solutions, and it is recommended that, as a means of minimizing attack, copper-rich steels be annealed at 1900°-2100°F. (1040°-1150°C.) and water-quenched. Intergranular corrosion of sensitized copper-containing austenitic steels in sulphuric-acid solutions is discussed and illustrated.

In cast alloys of the type discussed the amount of the copper-rich phase decreases with rise in nickel content, and for this reason the high-nickel grades, e.g., 20-29 chromium-nickel types, may show somewhat superior resistance to sulphuric-acid corrosion under severe conditions. From 1 to 3 per cent. molybdenum improves the corrosion-resistance of the copper-containing austenitic steels, but no particular advantage is gained by amounts of more than 2-2½ per cent. Silicon varies in effect with concentration of acid, and silicon content must also be dictated by foundry and rolling-mill considerations, and with regard to its effect on structure. Since silicon and molybdenum promote formation of sigma phase, the combined silicon + molybdenum content must be adjusted to minimize sigma formation.

The rôle of copper in the stainless steels is not yet fully understood: the authors briefly summarize some observations made on resistance to sulphuric - acid corrosion as a function of copper content.

Test results indicate that the highly alloyed copper-bearing chromium-nickel-molybdenum steels exhibit satisfactory resistance at 175°F. (80°C.) to sulphuric-acid concentrations up to 50-56 per cent. and above 85-90 per cent. In concentrations between 65 and 85 per cent., where acid attack is most severe, the steels may be considered usefully resistant up to 120°F. (50°C.). At boiling temperatures concentrations up to about 10-20 per cent. may be used. Permissible maximum temperatures depend on many factors, e.g., amount of corrosion which can be tolerated during the expected life of a part, effects of other solutions or substances in the sulphuric acid, aeration, velocity of the liquid, etc. No one grade of the complex steels can be recommended as superior to the others in every environment.

Sulphuric acid usually contains some oxygen in solution, and hence has an oxidizing capacity. In completely de-aerated solutions unusual corrosion rates may sometimes be observed in certain environments, particularly when the stainless steel has become active (depassivated) and is in contact with a more noble metal. Re-passivation may be accomplished by addition of oxidizing agents: typical lowering of rates of corrosion so effected are illustrated in the original. In sulphurous acid these steels are generally almost perfectly resistant, retaining their passive state at all concentrations and temperatures. Admixture of sulphuric acid, however, causes severe activation.

Resistance of Nickel-Chromium Stainless Steel to Mineral Acids and Inorganic Chlorides

L. B. GOLDEN, I. R. LANE and W. L. ACHERMAN: 'Corrosion Resistance of Titanium, Zirconium and Stainless Steel.' *Industrial and Engineering Chemistry*, 1952, vol. 44, Aug., pp. 1930-9.

Part I. Mineral Acids

A succinct review of previous work on resistance of titanium and zirconium to acids is followed by a report of tests in which the two metals were exposed to the action of various concentrations of sulphuric,

hydrochloric, nitric, phosphoric and mixed acids, and chlorine. The tests were made at several temperatures and under various conditions of aeration. One of the more corrosion-resistant types of stainless steel, Carpenter 20 (chromium 20, nickel 29, copper 3, molybdenum 2, per cent.), was subjected to identical tests, in order to obtain a basis of comparison, and in some of the tests a molybdenum-containing 18-8 was also included. Typical results are tabulated and shown in graphical form.

In sulphuric and hydrochloric acids all three materials (titanium, zirconium and Carpenter 20) showed, in general, greater resistance to corrosion in air-free than in air-saturated solutions. In sulphuric-acid solutions the stainless steel proved superior to titanium under all conditions, whereas zirconium gave better resistance than stainless steel to all sulphuric-acid solutions below 80 per cent. concentration. All three materials showed excellent resistance to all concentrations of nitric acid. In mixed acids both titanium and stainless steel behaved better than zirconium. At relatively low temperatures the addition of small amounts of nitric acid to sulphuric acid inhibited corrosion of both titanium and stainless steel, but such addition increased corrosion of zirconium. Of the three types of material tested, only zirconium was fully resistant to hydrochloric acid solutions. In phosphoric acid titanium proved satisfactorily resistant to all concentrations at lower temperatures only: the stainless steel showed better resistance than zirconium, especially in boiling solutions. Titanium was fully resistant to an atmosphere of water-saturated chlorine, whereas zirconium, Type 316 stainless steel, and the Carpenter 20 steel were badly attacked.

Part II. Inorganic Chlorides

One of the most attractive properties of titanium and zirconium is their resistance to chloride solutions, the handling of which gives rise to many problems in chemical engineering, due to the serious type of pitting corrosion produced in many metallic materials. This paper summarizes earlier data and records results of tests on titanium, zirconium and Carpenter 20, exposed to inorganic chlorides of many types, at various concentrations and temperatures. The tabular data reported are supplemented by photographs illustrating the condition of the respective materials after test. The solutions used included ferric, cupric, mercuric, stannic, nickel, manganous, sodium, ammonium, calcium, magnesium, barium, zinc, and aluminium chlorides.

With the exception of concentrated aluminium-chloride solution, titanium proved fully resistant to attack by all concentrations of these solutions. Tests in alkaline and alkaline-earth chlorides, on some lots of titanium produced by powder-metallurgy methods, resulted in a peculiar blister type of pitting, which is ascribed by the authors to the presence of impurities in the metal, particularly magnesium chloride inclusions. The only solution in which titanium showed excessive corrosion was 25 per cent. aluminium chloride at 100°C.

Stainless steels show poor resistance to heavy-metal chlorides, except in very dilute solutions at low temperatures. The tests confirmed the susceptibility of this type of material, in chloride solutions, to a pitting type of attack, and the resulting unsuitability of stainless steel for handling them, due to likelihood of rapid penetration and perforation. Concentrated solutions of sodium, ammonium, calcium and magnesium chlorides at elevated temperatures also cause varying degrees of pitting in stainless steel. Zirconium, unlike titanium, is not resistant to solutions of ferric or cupric chloride unless both concentration and temperature are low. In all other chloride solutions, however, it proved almost completely resistant.

Tests made on titanium and on Hastelloy C showed them to be almost completely resistant to hypochlorite solutions, but two types of stainless steel were badly attacked. In such solutions zirconium was highly resistant, but there was evidence of shallow embrittlement in the higher concentrations of hypochlorite, especially at elevated temperatures.

Resistance of Nickel-Chromium Stainless Steels to Nitric Acid

H. T. SHIRLEY and J. E. TRUMAN: 'Some Factors Affecting the Resistance of Austenitic Chromium-Nickel Steels to Attack by Hot Concentrated Nitric Acid.' *Jnl. Iron and Steel Inst.*, 1952, vol. 171, Aug., pp. 354-8.

An earlier report on the behaviour of various austenitic nickel-chromium steels in contact with boiling 70 per cent. nitric acid showed that 18-13-1 and 18-9-1 chromium-nickel-niobium types were free from deleterious effects associated with heat-treatment introduced by welding (*ibid.*, 1952, vol. 170, pp. 111-18; *Nickel Bulletin*, 1952, vol. 25, No. 4, pp. 115-16). The conclusion was drawn that for plant handling boiling 70 per cent. nitric acid the higher-nickel steel would be the safer choice, due to its greater austenitic stability.

The present paper deals primarily with tests covering various aspects of the attack of concentrated nitric acid on unwelded, normally heat-treated 18-13-1 steel: some tests on 18-9-1 and plain 25-20 chromium-nickel steel are included for comparison. The data obtained from exposures made under varying conditions indicate that a number of factors must be carefully considered, in order to ensure (1) correct interpretation of laboratory test results, and (2) adjustment of operating conditions in such a way as to secure optimum service from the various steels.

It is found that attack by boiling concentrated nitric acid results in some degree of intergranular penetration even in stabilized austenitic steels which are in a condition satisfactorily resistant to intercrystalline attack by other reagents. In such steels penetration does not usually proceed to a depth of more than one or two crystals below the surface, but there is an indication that acceleration of attack from the small losses of the early stages is related to the development of this penetration effect. Large-grained structures may then suffer higher rates of attack, because of the more extensive removal of crystals for a given amount of boundary penetration. Purity of the nitric acid used is a most important factor:—

(*a*) Supplies of high-purity acid from different

sources gave surprisingly different rates of attack, but this is not considered to be a point of great practical importance, since acid of this purity is probably not used in any industrial application.

(*b*) Of the acid radicals tested as contaminants, the most objectionable was found to be hydrofluoric acid. Addition of 0·1 per cent. by volume of concentrated (40%) acid produced acceleration of the order of six times in 48-hour tests. Similar additions of phosphoric and sulphuric acids had relatively small effects, and with additions of hydrochloric and nitrous acids no effect was observed.

(*c*) Contamination of the nitric acid from metallic radicals occurs as a result of solution of the steel: the effect may be cumulative, giving rise to serious acceleration of attack. For this reason, certain tests in which the necessary accumulation of dissolved products can build up may greatly exaggerate much smaller effects arising from other causes.

Effect of metallic contamination falls off very rapidly with decreasing concentration of acid, becoming negligible at 55 per cent. HNO_3. In practice the effect is unlikely to be serious up to 60 per cent. HNO_3.

The results of the tests reported indicate the existence of variable passivity effects, with a tendency to a build-up of resistance during breaks in testing for re-weighing. This may affect response in a succeeding test cycle to a much exaggerated extent, by modifying the early rise in metallic contamination in a 48-hour test.

Comparison of results of long-term (480-hour) tests on the three steels used indicates generally similar behaviour in the 1050°C. air-cooled condition, with possibly a slightly lower overall resistance for the 25-20 steel.

Stainless Steels for the Soft-Drinks Industry

J. M. BRYAN and J. W. SELBY: 'The Corrosion-Resistance of Stainless Steels towards Citrus Fruit-Squash Concentrates and towards Citric Acid-Sugar-Common Salt-Sulphur Dioxide Solutions.' *Jnl. Science of Food and Agriculture*, 1951, vol. 2, Aug., pp. 359-64.

The attention of the authors was directed, some years ago, to the occurrence of severe corrosion in a large mixing vat used for blending concentrated orange and lemon pulp (containing about 1000 p.p.m. of sulphur dioxide) with water, sugar, and other ingredients, before bottling. The mixture was sometimes allowed to stand overnight or, on rare occasions, over a week-end. During filling of the bottles the mixture was kept agitated, to ensure even distribution of the pulp. Initial temperature of the full batch was about 70°C. and this fell slowly as filling progressed. The final mixture was adjusted to contain: citric acid 4, sodium chloride 0·5, sucrose 30, per cent., sulphur dioxide 300 p.p.m. The vat, which was rectangular, was fabricated from welded sheet; it had pitted badly along several narrow bands roughly corresponding to the position of the welds, and finally failed after 6 months' use.

In view of the proposed extension of use of stainless steel in the fruit-products and soft-drinks industries, a detailed study was made to determine the relative suitability of a range of austenitic stainless steels for handling hot citrus-fruit concentrates containing sulphur dioxide. The work was done as two parallel investigations, in separate laboratories using, respectively, a hot solution of citric acid, sugar, common salt and sulphur dioxide, and natural citrus fruit concentrates containing sulphur dioxide. The types of steel exposed for test are shown in the table below:

Table I

Composition of the Stainless-Steel Samples

Type of Steel	C %	Si %	Mn %	Cr %	Ni %	Ti %	Mo %
A	0·12 (max.)	0·6	0·4	18	8	0·6	—
B	1·10 (max.)	—	—	17-20	10-11	5 × C	—
C	0·07 (max.)	—	—	17·5-18·5	7·5-8·5	0·25-0·40	—
D	0·07 (max.)	0·3	0·5	18	8	—	2·75
E	0·10 (max.)	—	—	16-18	11-13	0·2-0·3	2-2·5
F	0·12 (max.)	—	—	18-19	9-10	0·25-0·40	1·5-2·0

Full details are given of experimental methods and individual results.

The data obtained show conclusively that stainless steels containing 2-3 per cent. of molybdenum have a markedly greater resistance to corrosion by hot citric acid–sugar–common salt-sulphur dioxide solutions in general, and by citrus-squash concentrates in particular, than similar steels without molybdenum. Reasonable service life may be expected for equipment used for handling such solutions, provided that it is made from an austenitic stainless steel of Type D, E or F shown in the table. Welding tends to lower the resistance of even the molybdenum-bearing stainless steels to attack by citrus-fruit concentrates, and it is recommended that, so far as is possible, welding should be avoided in designing equipment for such purpose.

Corrosion by Water: A.C.S. Symposium

'Symposium on Water Corrosion.' *Industrial and Engineering Chemistry*, 1952, vol. 44, Aug., pp. 1736-95. Reprints of papers presented, in part, before the Division of Water, Sewage, and Sanitation Chemistry, at the Diamond Jubilee Meeting of the American Chemical Society, 1951.

The papers presented dealt with the following aspects of the subject: corrosion control in water systems; cooling-water problems in Metropolitan New York; effects of velocity and of temperature, on corrosion by water; corrosion inhibitors; phosphate and phosphate-chromate protective treatment of metals; cathodic protection of steel; the pitting corrosion of aluminium. The paper on effect of velocity on corrosion, presented by H. R. COPSON, included data on resistance of cupro-nickel to sea water, as influenced by velocity, and results of cavitation-erosion tests on nickel-containing non-ferrous and ferrous materials.

Potentials of Stainless Steels in Flowing Sea Water

K. M. HUSTON and R. B. TEEL: 'Some Observations of the Potentials of Stainless Steels in Flowing Sea Water.' *Corrosion*, 1952, vol. 8, July, pp. 251-6.

Available information on the e.m.f. potentials of stainless steels has hitherto been limited to a relatively few grades of steel; no data have been published on free-machining types or on the newer varieties of stainless steel. This paper reports results of tests made, at the Harbor Island Marine Test Station, on nine standard types: A.I.S.I. 410, 416, 430, 430F, 431, 303S, 304, 316 and 347, and on three new grades: Armco 17-4 PH (containing copper), Armco 17-7 PH (containing aluminium), and Armco 17-14 Cu-Mo. The test equipment is described.

Effects of composition, heat-treatment, free-machining addition, and crevice corrosion, on e.m.f. potentials, are discussed. The main conclusions drawn are given below:—

Maximum spread in the average potentials of the different grades and conditions of stainless steels is ordinarily about 200 m.v. in turbulent sea water. Under such circumstances, possible galvanic difficulties should be anticipated when stainless steel of one composition or heat-treatment is joined with another one in a galvanic couple. This is especially true where the relative area of the more noble material is large compared with that of the less noble one.

In general, the composition of the stainless steels tested bears a general relationship to the e.m.f. potentials in turbulent sea water. With the exception of Type 431, which showed unexpectedly noble values, the straight-chromium grades had the highest average potentials: the chromium-nickel steels, including the precipitation-hardening types, had the next highest average potentials, and the chromium-nickel steels containing molybdenum had the lowest.

The effect of small additions of sulphur, used as a free-machining element, is unpredictable, but it can be assumed that the addition of the sulphur will cause an increase in the average potential of the steel. An exception to this was observed in the case of Types 416 and 410 steels which had undergone a tempering treatment, in which case the Type 416 steel containing the free-machining element was more noble than its unmodified counterpart.

The average potentials of the straight-chromium steels were highly sensitive to effects of composition and especially of heat-treatment, which seemed to have more effect than the addition of sulphur as a free-machining element. Type 416 steel proved more noble in the tempered condition, while Type 410 showed greater nobility in the hardened and stress-relieved condition. In the nickel-containing steels differences in condition appeared to have less effect on potential, although in the 17-7 PH steel there seemed to be a trend towards more noble potentials in the steel hardened by cold work, in comparison with the same steel hardened by heat-treatment.

Properties of 90-10 Cupro-Nickel containing Iron

W. C. STEWART and F. L. LAQUE: 'Corrosion-Resisting Characteristics of Iron-Modified 90:10 Cupro-Nickel Alloy.' *Corrosion*, 1952, vol. 8, Aug., pp. 259-77.

This paper presents a comprehensive summary of information on the characteristics of the iron-modified 90-10 copper-nickel alloy which has been developed for use in applications for which a nickel content lower than that of the 30 per cent. standard alloy can be tolerated. Like the 70-30 and 80-20 alloys, it shows unusually high resistance to attack by salt water, and is designed primarily for use in marine service.

Following a review of research which has been carried out in U.K. and U.S.A. on iron additions to higher-nickel cupro-nickels, an account is given of observations made by various investigators on the influence of iron additions to the 90-10 alloy, and of studies directed by the present authors on this type of material. Behaviour of these alloys under various conditions of exposure to sea water is described, e.g., quiet immersion, and exposure at moderate and high velocities. The section dealing with high-velocity experiments includes results of jet-impingement and erosion tests, and of tests made in model condensers and piping systems. Information is also given on the fouling characteristics of the alloy, and its galvanic behaviour.

Experience with the alloy in sulphide-polluted, as well as clean, sea water is described, and the effects of chlorination of sea water, on the corrosion-resistance of the 90-10 cupro-nickels, are discussed in relation to the influence of iron content and concentration of chlorine.

Although the alloy was primarily developed to resist attack by sea water, its composition is such as to confer a good degree of resistance to corrosion in other media. Detailed data on this aspect of the subject are to be published shortly: the information now given indicates that its combination of corrosion-resistance, relatively low susceptibility to season-cracking, and immunity from dezincification will favour the use of iron-containing 90-10 in steam-plant feed-water heaters.

Attention is directed to the satisfactory corrosion-resistance of welded and brazed joints in the alloy, and the review closes with data on typical mechanical

properties and thermal conductivity. It is stated that over 2,000,000 lbs. (890 tons) of the alloy have already been put into service in U.S.A., of which about 50 per cent. has gone into steam-plant heat-exchangers, where the performance record to date is good.

Iron-containing Cupro-Nickel: 'Kunifer 30'

'Cupro-Nickel Alloys.' *Railway Gazette*, 1952, vol. 97, July 18, p. 83.

The Metals Division of Imperial Chemical Industries, Ltd., has added Admiralty-quality 70-30 cupro-nickel to its 'Kunifer' range of nickel-copper alloys containing iron and manganese. The 'Kunifer' series originally covered the 5 and 10 per cent. nickel alloys referred to in British Patents 577,065 and 578,283, taken out by British Non-Ferrous Metals Research Association, but since the I.C.I. 'A.E. Super Nickel' condenser-tube alloy has for many years contained iron and manganese (in accordance with Admiralty specification 3T.102), assignment of a 'Kunifer' designation is a natural measure of standardization. The three alloys are numbered according to their nickel contents: 'Kunifer' 5, 10, and 30, respectively.

Nickel-bonded Chromium Carbide

J. D. KENNEDY: 'Chrome Carbide Provides High Corrosion Resistance.' *Materials and Methods*, 1952, vol. 36, Aug., pp. 166-74 (even numbers only); see also *Steel*, 1952, vol. 181, Aug. 4, pp. 92-4.

The article describes the properties and uses of grade 608 chrome carbide, the first of a series of new cemented chromium carbides which is being developed by the Carboloy Department of General Electric Company, Detroit. The material contains 83 per cent. chromium carbide and 2 per cent. tungsten carbide; it is made by powder-metallurgy methods, using 15 per cent. of nickel as binder. It is light in weight, and is claimed to have high resistance to corrosion, erosion, abrasion, and oxidation. Resistance of the carbide alloy to salt spray is outstanding, and in sulphuric-acid and nitric-acid tests it has shown superiority to 18-8 stainless steel. Oxidation and steam-erosion tests indicate also a useful sphere of service at elevated temperatures. Data on the physical properties and corrosion-resisting characteristics of the new material are tabulated, and some indication is given of the many applications for which it is suited by virtue of its intrinsic qualities.

Nickel and Monel for Equipment Handling Fluorine and Hydrofluoric Acid

R. LANDAU: 'Corrosion by Fluorine and Fluorine Compounds.' *Corrosion*, 1952, vol. 8, Aug., pp. 283-8.

The physical and chemical properties of fluorine are discussed, with particular reference to its high chemical reactivity. The nature of the corrosion which may occur in contact with fluorine is described, and particulars are given of materials which may satisfactorily be used for handling the element. In this connexion the outstanding suitability of nickel and Monel is emphasized, with some reference to specific uses of the two materials.

Monel is more universally applicable to the handling of aqueous solutions of hydrofluoric acid over a wide range of temperature and concentration, than any other common metal. Nickel is also useful for contact with the acid in many conditions, but shows a somewhat higher rate of corrosion than Monel, particularly at relatively high temperatures and low concentrations. Anhydrous hydrogen fluoride at elevated temperatures is successfully handled in both Monel and nickel, and also by copper. The review also includes discussion of the corrosion-resistance of the fluorocarbons, which are usually chemically inert at normal temperatures. An outstanding member of this group of compounds is Teflon.

Pickling Containers made from Salvaged Stainless-Steel Scrap

'Waste Basket Saves Money and Materials.' *Nickel Topics*, 1952, vol. 5, No. 5, p. 5.

Fabrication of pickling baskets from stainless-steel scrap produced in punch-pressing of exhaust-system flanges has materially lengthened the life of pickling equipment in the plant of Ryan Aeronautical Company. The containers described are about 5 ft. long, $2\frac{1}{4}$ ft. wide and nearly 2 ft. high, and are used to convey stainless-steel parts through the pickling cycle, in the production of aircraft-engine parts. They were formerly made of wood; weighting with lead was necessary to keep them submerged, and because the lead was readily attacked by the acids of the baths, it was necessary to enclose the weights in protective stainless-steel coverings. The wood containers tended to rot rapidly, causing contamination in the tanks, and they were totally unsuitable for use in molten salt baths, due to risk of ignition. The stainless-steel baskets, made by straightening scrap strip, cutting to length, and welding, give a service life of three months, by comparison with the ten-day average for the wooden baskets.

Nickel-Chromium Stainless Steel Filters

'Stainless Steel Filters.' *Iron and Steel*, 1952, vol. 25, Sept., p. 417.

A new application of 18-8 stainless steel powder is its use, in sintered form, as a filtering medium. This material is highly resistant to many corrosive substances, and a new method of producing the powder, developed by the B.S.A. Group Research Centre, ensures that individual grains are free from internal stress and that particle-size distribution is controlled within close limits. Graded powder is mixed with a porosity-producing agent which volatilizes during the initial sintering operation, and subsequent pressing in dies results in a uniform compact of controlled porosity. The 'green' pressings, usually in sheet form, are initially sintered, and finally re-sintered at a high temperature, in a reducing atmosphere of dry hydrogen, a procedure which promotes diffusion-welding of mutually placed angular particles of powder, thus producing porous-metal compacts of high strength and ductility.

As a result of investigation on methods of joining the material for formation of filters of required shape, a new technique has been evolved, by which complicated final forms of different filters may be made from simple unit pressings. Details of the range of filters immediately available are given in this note.

Monel-Clad Masts on Submarines

'Clad Metal Masts on Subs Cut Costs.' *Materials and Methods*, 1952, vol. 36, Aug., pp. 182, 184.

A new design of extensible radio and radar mast for snorkel-equipped submarines of the U.S. Navy provides for seamless drawn low-alloy steel tubes, clad with Monel. The original design called for tubes forged and pierced from solid billets of stainless steel.

Extensible mast tubes are required to have high strength with minimum weight, in order to support antennae without undue vibration when at snorkel depth and maximum snorkel speed. The tubes must also have smooth, accurately machined exteriors, to provide good bearing surfaces for extension, retraction and rotation. A further essential is a degree of ruggedness sufficient to withstand the action of the waves.

The following figures are given to demonstrate the economy effected by introduction of the Monel-sheathed low-alloy steel tubes in place of the stainless-steel masts:—

'Under the original design, masts would have to be forged and pierced from solid billets of 18-8 stainless steel having a total weight, for all the masts to be made, of 11,320 tons. The total finished weight of the masts would be only about 400 short tons. This meant that 10,920 tons of metal would have to be machined away and scrapped.

The total program for the new tubes required about 340 tons of steel tubing, very little of which is machined away, and 125 tons of Monel cladding, of which 50 tons are machined away.'

Instability of Etchant Used for Stainless Steels

L. H. SATZ: 'Discard this Etchant Promptly.' *Metal Progress*, 1952, vol. 62, Aug., p. 96.

This note gives a warning that although the well-known etchant for stainless steels (20 ml. conc. HF, 10 ml. conc. HNO_3, 30 ml. glycerol) is safe when used immediately after preparation, an exothermic reaction occurs on standing, and red fumes of nitrogen dioxide are evolved. The dormant period and the degree of violence of the reaction depend on the ambient temperature, and are also affected by contact of stainless steel with the solution. Some typical examples illustrating the influence of these factors are cited. The cause and nature of the reaction occurring are briefly discussed.

Acoustic Method of Determining Intercrystalline Corrosion

See abstract on p. 231.

Chemical Analysis of Nickel and Nickel Alloys: Recommended Procedures

See abstract on p. 236.

Spectrographic Determination of Manganese and Silicon in Nickel-Alloy Steels

M. ONGARO: 'Notes on the Quantitative Spectrographic Analysis of Manganese and Silicon in Special Steels.' *Metallurgia Italiana*, 1952, vol. 44, June, pp. 221-5.

Determination of the influence of the principal alloying elements present in steels, on the spark intensity in alloy steels, and of the variations in the excitation lines of manganese and of silicon as influenced by four different light sources. The effect of the metallurgical history of the specimen on determination of these elements is also considered, and recommendations are made with regard to the best sources for determination of manganese and silicon in high-speed and in stainless steels.

Determination of Tantalum and Niobium in 18-8 Stainless Steels

W. J. POEHLMAN and R. E. SARNOWSKI: 'Spectrographic Determination of Tantalum and Columbium in 18-8 Stainless Steels.' *Jnl. Optical Soc. of America*, 1952, vol. 42, July, pp. 489-92

Full form of paper reported from abstract source in *Nickel Bulletin*, 1952, vol. 25, No. 2, p. 52.

Rubber Forming of Nickel-Chromium Steel Tubes

'Spherical Joint: Rubber Forming of Stainless-Steel Tubes.' *Aircraft Production*, 1952, vol. 14, Sept., p. 297.

The article describes, with diagrams, a method adopted by Accles and Pollock, Ltd., Oldbury, Birmingham, for manufacture of a spherical joint for exhaust systems in Bristol engines. The joint is made between two stainless-steel tubes to specification T.55 (carbon 0·16 max., nickel 8-12, chromium 16-20, per cent.): the inside diameter of the tubing is 2¼-in. and it has a wall thickness of 20 s.w.g. As formed, the tubing is in the fully softened and descaled condition. In producing the joint forming is effected by bulging the tubes by pressure applied to a rubber plug under a hydraulic press.

Welding of Stainless-Steel Liners: Summary Information

H. THIELSCH: 'Stainless-Steel Applied Liners. Review of Published and Unpublished Information.' *Welding Jnl.*, 1952, vol. 31, July, Suppl., pp. 321-37.

'Applied liners' are defined as 'composite plates, where a relatively thin sheet of a corrosion- or heat-resisting metal is bonded intermittently to a backing steel, usually a commercial grade of mild or low-alloy steel.' In this respect applied liners differ from clad sheets, in which the corrosion- or heat-resisting sheets are integrally bonded to the backing steel. In the fabrication of applied liners the base steel and the stainless-steel liners are, respectively, plate and sheet of the thickness desired for each in the final plate. The liner is usually bonded intermittently to the base steel by one of four welding processes: (1) spot or seam welding, (2) plug welding, (3) strip welding, (4) through

welding. Spot- or seam-welding is usually applied on plates prior to fabrication into vessels or other structures: the other procedures are used primarily to attach liners into vessels or other parts already fabricated. Typical procedures are described and illustrated, representative applications of liners are shown, and the characteristics of the bond zone formed in lining are discussed in relation to their possible effect on service life of the lined part.

In connexion with heat-treatment, it is pointed out that the alloy material is supplied in its fully annealed state, with maximum corrosion-resistance, and that this condition must not be seriously lowered by fabrication operations or service conditions. Stress-relief treatments of the carbon steel can often be carried out on applied liners within the range of temperatures permitted by the A.S.M.E. Code without deleterious effects to the liner. Austenitic applied liners may be stress-relieved at temperatures below 1000°F. (538°C.) by holding at temperature for longer periods, as permitted by the Code. Vessels lined with straight-chromium stainless steels are, when necessary, stress-relieved at temperatures between 1150° and 1250°F. (620° and 675°C.).

Tests used on applied liners are also reviewed in this paper. Air-pressure and hydrostatic tests are very commonly employed: procedure is described. Spot- or seam-resistance welded liners are usually bond-tested at pressures up to 2,000 p.s.i. Other forms of test, e.g., radiographic methods, and tests used for determining the presence of cracks and other flaws, are also described.

The advantages of applied liners are considered: chief among them are (1) the possibility which they offer of applying all types of high-alloy and high-temperature materials, which cannot always be used in the form of clad material, and (2) the possibility of inspecting the liner material, prior to application, for gauge, surface finish, composition, and mechanical properties.

The review of existing information on the various aspects of the subject outlined above is supported by a *bibliography* of 68 items.

Seam Welding of Thin Inconel Sheet

See abstract on p. 236.

Vibratory Treatment of Stainless Steel during Welding

J. W. WELTY: 'Effect of Vibration on Weld Metal.' *Welding Jnl.*, 1952, vol. 31, Aug., Suppl., pp. 361-6.

For several years past there has been an increasing interest in beneficial effects which might be derived from application of sonic and ultrasonic vibrations to metals under welding conditions. This paper describes experiments made by Solar Aircraft Company, to determine the influence of such treatment on the microstructural solidification pattern and the mechanical properties of welds in A.I.S.I. Types 321 and 347 nickel-chromium steels, welded by both arc and resistance processes. Experimental set-up is described and illustrated. Tensile and torsion-shear tests were made to evaluate the properties of vibrated *vs.* unvibrated welds, and macro- and micro-structure were examined.

Although the results of the tests varied somewhat widely and no high degree of consistency was observed in the purely qualitative data obtained, the general trend slightly favoured vibrated samples, and the authors conclude that the evidence is sufficiently strong to indicate the desirability of further work on vibration techniques for fusion and resistance welding of stainless steels.

PATENTS

Production of Porous Nickel Accumulator Plates

In making porous metal plates, e.g., by sintering nickel powder, the powder is charged from a hopper to moulds having rough surfaces and mounted on a conveyor. Rough cover plates are dropped on to the mass from a magazine, and the plates are carried on the conveyor through a sintering furnace and a cooling chamber, and subsequently past magnets so arranged that the cover plates and the sintered plates drop off the conveyor at different points.

M. A. COMLEY, assignor to INTERNATIONAL NICKEL CO. OF CANADA, LTD. *Canad. Pat.* 484,721.

See also following patent.

A related patent covers production of sintered nickel accumulator plates (80-85 per cent. porosity) made by applying successive layers of B-nickel powder to a rough-surfaced support (e.g., a ceramic plate), and sintering-on each layer in turn. The support prevents lateral contraction during sintering.

H. W. G. HIGNETT, assignor to INTERNATIONAL NICKEL CO. OF CANADA, LTD. *Canad. Pat.* 484,722.

Brazing of Nickel

Nickel parts are brazed together (using molybdenum as brazing material) by heating to 1350°-1455°C. in a reducing atmosphere, so that a molybdenum-nickel alloy is formed which contains nickel considerably in excess of the amount present in the eutectic alloy. The parts may be held together during the brazing operation by first tack-welding them.

BRITISH THOMSON-HOUSTON CO., LTD.
Brit Pat. 676,149; see also *Brit. Pat.* 625,195.

Preparation of Pure Nickel Hydroxide

Pure nickel hydroxide is made by precipitation (at pH above 12·5) from an aqueous solution of a nickel salt with a water-soluble hydroxide, and treatment of the precipitate (e.g., by Soxhlet extraction) with an anhydrous organic solvent chosen from the group of alcohols with 1 to 5 carbon atoms and their ethers, furanes and hydrofuranes, pyrans and hydropyrans, and ketones with 1 to 6 carbon atoms.

INTERNATIONAL NICKEL CO., INC., assignee of W. J. KIRKPATRICK. *U.S. Pat.* 2,602,070.

Production of Nickel Sulphate

Solutions of nickel and/or cobalt sulphates are purified from iron by treatment with an oxidizing gas mixture containing a small percentage of sulphur dioxide and then precipitating the iron as ferric hydroxide by adding a base. The process may be applied to the solution obtained by sulphuric-acid leaching of calcined and reduced nickel matte.

MOND NICKEL CO., LTD., DE W. H. WEST and A. E. WALLIS. *Brit. Pat.* 672,993.

Nickel Treatment of Surfaces Prior to Enamelling

Surfaces which are to be enamelled are coated with nickel, and annealed in a mildly oxidizing gas to produce a light scale. The scale is then removed by acid pickling. The nickel may be applied by electrodeposition or as a nickel salt solution which is dried on. The surface may also be decarburized at any convenient stage, and a second nickel coating may be given immediately before enamelling. Surfaces thus prepared are suitable for coating with a single coat of white enamel.

ARMCO INTERNATIONAL CORPN. *Brit. Pat.* 674,490.

Coating of Thermionic Valve Cathodes

The rate of activation of thermionic valve cathodes consisting of a nickel-aluminium or cobalt-aluminium alloy core coated with one or more alkaline-earth oxides is increased by incorporation of 1 per cent. or more by weight of nickel oxide in the coating. The preferred coating is made by thermal decomposition of a mixture of calcium, strontium and barium carbonates and nickel oxide.

SYLVANIA ELECTRIC PRODUCTS, INC. *Brit. Pat.* 673,237.

An electron-emissive coating for cold cathodes, giving long life and a sustaining voltage of less than 70 volts, consists of barium oxide having dispersed in it 1-3 per cent. of nickel, at least some of the nickel being in solid solution in the barium-oxide lattice. The coating is preferably applied to a nickel base as a mixture of 90 per cent. barium carbonate and 10 per cent. nickel oxide. Heat-treatment is at 1300°C. or above.

WESTERN ELECTRIC CO., INC. *Brit. Pat.* 673,458.

Casting Alloy for Food-Processing Machinery

The copper- and iron-free alloys specified contain nickel 76-79, zinc 7-9, tin 6·5-8·5, lead 2-5, manganese 1·5-2, per cent.

R. W. THOMAS, assignor to WAUKESHA FOUNDRY CO. *Canad. Pat.* 483,092.

Welding of Nickel-Copper Alloys

The weldability of nickel-copper alloys (copper 25-35 per cent.) is improved, with special reference to lessening of tendency to hot-cracking, by incorporation of 0·5 to 3·0 per cent. of niobium. Such an addition overcomes the deleterious effects of lead which may be present as an impurity.

MOND NICKEL CO., LTD. *Brit. Pat.* 675,806.

Electrodes for Surfacing and Welding

Nickel-copper overlays and welded joints which are low in carbon, and therefore ductile and crack-free, are obtained by the use of an electrode consisting of nickel-copper alloy core (preferably nickel 60-70, copper 23-30, per cent., with optionally some aluminium) and a flux-forming coating containing, by weight, $CaCO_3$ 20-40, CaF_2 5-35, bentonite 2-5, niobium (as Fe-Nb) 3-12·5 parts, and a water-dispersible binder, with or without TiO_2 up to 35 parts, manganese (as Fe-Mn) 8·5 parts, and titanium (as Fe-Ti) up to 2 parts. Some or all of the niobium may be contained in the core instead of in the coating.

MOND NICKEL CO., LTD. *Brit. Pat.* 677,406.

Precipitation-Hardenable Nickel-Aluminium Bronze

The following composition is cited: aluminium 6·1-8·5, nickel 6-15, iron 6·1-12, per cent., balance copper. One or more of the following elements may also be present within specified limits:—manganese, chromium, phosphorus, lithium, cobalt, silver, cadmium, beryllium, titanium, zirconium. The alloys are solution-treated at a temperature not below 900°C., quenched and temper-hardened at 400°-600°C.

W. P. FENTIMAN, E. R. LYNAM and IMPERIAL CHEMICAL INDUSTRIES, LTD. *Brit. Pat.* 674,127.

Deoxidation of Nickel-Iron Magnetic Alloys

In melting nickel-iron-molybdenum magnetic alloys (nickel 75-85, molybdenum 2-7, manganese 0-2·0, per cent., balance iron), the conventional use of strong deoxidizers in the last stage has been found to hinder development of optimum magnetic properties on subsequent heat-treatment. The effect is considered to be due to formation of dispersions of stable oxides. This patent covers a process for melting such alloys, characterized by the fact that at no time when oxidizing conditions are present in the melt are deoxidizers added which have a greater affinity for oxygen than has manganese, and which are capable of forming stable oxides. Deoxidation is effected by manganese. The alloy is subsequently heat-treated in dry hydrogen at a temperature above 1100°C., but below that of the melting point of the alloy, and is subjected to controlled cooling between 600° and 300°C.

WESTERN ELECTRIC CO., INC.
Brit. Pat. 678,339. (Patent of Addition to 638,210.)

Production of Nickel-Iron Powder Magnetic Cores

Finely divided particles of magnetic material, e.g., nickel-iron or nickel-copper-iron alloys, are coated with an insulating material consisting of china clay, waterglass, and gamma alumina, and are then coated with an organic compound of high molecular weight, before forming the core to shape under pressure. The material of high molecular weight may be a thermosetting resin or a cellulose derivative such as methyl cellulose.

GENERAL ELECTRIC CO., LTD., H. BAILEY and H. F. DAVIES. *Brit. Pat.* 676,136.

Preparation of Surfaces of Nickel-Iron Alloys for Wetting with Mercury

Ferrous alloys, particularly Permalloy types containing 45 or 52 per cent. nickel, are prepared for wetting with mercury by producing on them an oxide layer which is then reduced, e.g., by heating in moist hydrogen. The surface may be first prepared by recrystallizing the metal by means of heat-treatment producing large crystals, and by forming channels between the crystals, e.g., by sand-blasting or etching.
WESTERN ELECTRIC CO., LTD. *Brit. Pat.* 674,960.

Composition and Treatment of Anisotropic Permanent Magnets

The composition of the magnets is given as nickel 10-30, aluminium 6-11, cobalt 12-30, copper 0·5-8, per cent., with additions of both niobium and tantalum. The limits of the combined addition are 0·5-4·5 per cent., preferably 1-3 per cent., provided that Nb:Ta is from 3:1 to 1:3, but excepting the combination 1·5 per cent. niobium and 1·5 per cent. tantalum. The balance of the alloy is iron. Cooling from the solution temperature through the Curie point is carried out in a magnetic field.
WM. JESSOP AND SONS, LTD. (inventors, D. A. OLIVER and D. HADFIELD). *Brit. Pat.* 676,881. (Patent of addition to 659,527.)

Treatment of Nickel-containing Permanent Magnets

Cast or sintered magnets of the aluminium-nickel-cobalt-copper-iron type having high coercive force and $(BH)_{max.}$ up to or more than 20×10^6 gauss-oersted are made by tempering for at least 30 hours at 540°-600°C. an alloy of the following composition: aluminium 7-9, nickel 18-22, cobalt 16-20, copper 2-6, niobium 1-2, titanium 4·5-3·0, per cent., balance iron. The alloy may be solution treated at 1200°-1300°C. prior to tempering and cooled from that temperature at a rate of not more than 2°C./sec. If desired, this treatment may be carried out in a magnetic field.
WM. JESSOP AND SONS, LTD. (inventor, D. HADFIELD). *Brit. Pat.* 677,157.

Copper-Nickel-Cobalt Permanent-Magnet Alloy

Alloys containing copper 20-85, nickel 10-50, cobalt 5-70, per cent. are heated at 1100°C., slowly cooled to 800°-870°C., subjected to mechanical working, reheated to 1100°C. for a few minutes, quenched, and finally aged at 575°-650°C.
CANAD. GENERAL ELECTRIC CO., LTD., assignee of J. D. SEAVER. *Canad. Pat.* 484,286.

Nickel Alloys in Bellows for Sealing to Glass

Metallic bellows suitable for welding directly to glass comprise a seamless container with one or more corrugated walls formed of an alloy containing iron 50-56, nickel 30-35, cobalt 13-18, per cent., e.g., Fernico, Kovar, or Nilo K.
D. H. GIBSON-WOOD, F. GRUNEWALD and FERGUSON PAILIN, LTD. *Brit. Pat.* 677,776.

Precipitating-Hardening Watch- and Clock-Spring Alloys

The following composition is covered: cobalt 20-45, nickel 20-35, iron 10-25, tungsten 0-10, molybdenum 0-10, chromium 0-20, tantalum 0-5, per cent., together with 1-5 per cent. each of niobium and titanium, the titanium + niobium being within the limits 3-7 per cent.
E. P. DUBOIS, B. E. SIEGRIST and C. H. WAKKER. *Brit. Pat.* 675,622.

Complex Stainless Alloys for Watch Springs

Springs suitable for watches are made from an alloy containing iron 10·0-20·0, nickel 10·0-47·6, cobalt 21·0-50·0, molybdenum 6·1-10·0, chromium 10·0-18·0, tungsten 4·0-10·0, beryllium 0·05-3·0, titanium 0·1-3·0, carbon 0·05-0·6, manganese 1·0-6·0, vanadium 0-6·0, copper 0-6·0, aluminium 0-6·5, silicon 0·1-1·0, per cent. Limiting percentages are specified for certain combinations of the elements mentioned, and a preferred composition is given.
R. STRAUMANN. *Brit. Pat.* 674,839.

Austenitic Steel Magnetic Recording Wire

Sound-recording wire of 18-8 stainless steel is subjected to a final annealing for 1 to 3 seconds at 1000° to 1200°F. (538° to 648°C.) in an inert atmosphere after it has been cold drawn. Wire so treated has a tensile strength of at least 280,000 p.s.i. (125 tons per sq. in.) and an average intrinsic coercive force above 200 oersted, also a minimum intrinsic coercive force not substantially different from the maximum intrinsic coercive force by which the wire is readily erasable.
NAT. STANDARD CO., assignee of O. E. ADLER. *Brit. Pat.* 673,824.

Stainless steels suitable for magnetic recording wire or tape contain carbon 0·02-0·20, chromium 16-20, nickel 6-15, manganese 0·20-2·5, per cent., balance iron, in proportions consistent with the formula:—

$$\%\,Cr \times (\%\,Ni + \tfrac{1}{2}\,\%\,Mn + 20 \times \%\,C) = X$$

Where X = 170 to 240, and 40-80 per cent. cold work is needed for X = 170 to 210 and over 80 per cent. is required for X = 210 to 240.

Niobium (8 to 15 × % carbon) may be present to control grain size; in such case the formula becomes:

$$\%\,Cr \times (\%\,Ni + \tfrac{1}{2}\,\%\,Mn + 0{\cdot}40) = X$$

The steels have coercivity of 100-300 oersted and retentivity of 1000-3000 gauss at a field strength of 1000 oersted.
F. K. BLOOM, assignor to ARMCO STEEL CORPN. *U.S. Pat.* 2,590,074.

Creep-Resisting Nickel-Chromium-Cobalt Alloys

Austenitic alloys showing good creep-resistance and ductility at high temperatures contain carbon 0·2-1·0, silicon 0·1-1, manganese 0·1-1·2, nickel 10-20, cobalt 35-50 (Ni + Co 55-65), chromium 15-25, vanadium 1·5-4·5, tungsten and/or molybdenum 0·5-3·0, niobium 0·5-3, iron 3-20, per cent. It is specified that

vanadium+tungsten+molybdenum+niobium shall be 4-9 per cent.

The alloys are preferably solution-treated at a temperature 20°-150°C. below their incipient melting point, and subsequently warm worked at 600°-900°C. Properties are cited for typical alloys after given treatments.

WM. JESSOP AND SONS, LTD. (inventors D. A. OLIVER and G. T. HARRIS). *Brit. Pat.* 674,021.

Creep-Resisting Alloy

The following composition is given for alloys suitable for gas-turbine blades and similar applications:—carbon less than 0·25, chromium 12-20, nickel 10-16, silicon 0·5-3, manganese less than 3, tungsten 1-3, vanadium 0·3-1, niobium 0·5-1·5, tantalum 0·5-1·5, per cent. Preferred compositions are given.

GEBR. BÖHLER AND CO., A.G. *Austrian Pat.* 163,612.

Fabrication and Heat-Treatment of Precipitation-Hardened High-Temperature Alloys

Parts such as blades for gas turbines are manufactured from precipitation-hardenable alloys containing at least 50 per cent. of nickel or nickel+cobalt, and 5-45 per cent. of chromium, with one or more of the following elements: molybdenum, tungsten, iron, manganese, aluminium, vanadium, titanium, niobium, silicon, carbon. Carbon is specified as not more than one per cent., titanium and silicon are each not more than 5 per cent., the other elements are each less than 25 per cent., and the total of the added elements is restricted to 40 per cent. The following process of manufacture is cited:—

The major part of the hot shaping is first carried out and this is followed by a solution treatment (at 1050°-1200°C.) and a refining process, which consists of the remaining part of the hot-work shaping, and a heat-treatment at 850°-1050°C. Finally, the alloys are precipitation-hardened by treatment at 700°-800°C.

ROLLS-ROYCE, LTD. (inventors, H. E. GRESHAM, M. A. WHEELER and A. DUNLOP). *Brit. Pat.* 674,723.

See also following patent.

High-temperature alloys of the type described in the preceding abstract are subjected to the following treatment:—hot-work shaping at elevated temperature, solution heat-treatment at 1050° to 1200°C., machining to finished size, short-time heat-treatment at 850°-1050°C. and final precipitation-hardening treatment at 700° to 800°C.

ROLLS-ROYCE, LTD. (inventors, H. E. GRESHAM, M. A. WHEELER and A. DUNLOP). *Brit. Pat.* 674,724.

Composition of Creep-Resisting Stainless Steel

Austenitic stainless steel having good hot-working properties and resistance to stress-rupture, creep and corrosion at high temperatures is of the following composition: chromium 12-22, nickel 0·5-10, cobalt 4-40, manganese up to 2, molybdenum 1-4, copper 2-4, titanium 0·15-0·75, niobium 0·20-1·10, carbon up to 0·35, per cent., balance iron. Heat-treatment consisting of solution heating at 2040°-2250°F. (1115°-1230°C.), quenching, and ageing at 1200°-1500°F. (650°-815°C.) to precipitate copper, titanium and niobium, is also claimed.

ALLOY RESEARCH CORPN. *Brit. Pat.* 678,616. (Patent of addition to 636,392.)

Carbide-forming Additions to Steel for High-Temperature Corrosion-Resisting Applications

Austenitic steels suitable for use at temperatures of 800°-1300°F. (425°-705°C.), e.g., in chemical plants, turbines, etc., contain carbon 0·03-0·10, per cent., and from 4-15 times as much of one or more of the carbide formers titanium, niobium, tantalum, zirconium. The remaining details of composition are: boron 0·01-0·10, chromium 17-19, nickel 11-12, manganese 0·2-2·0, per cent., balance iron.

S. F. URBAN and G. F. COMSTOCK, assignors to NATIONAL LEAD CO. *U.S. Pat.* 2,602,028.

Hot-Workable Nickel Alloy

The following composition is specified for a corrosion-resisting hot-workable alloy: chromium 17-24, molybdenum 3-5, iron less than 10, copper 1·5-4, carbon 0·02-0·15, per cent., balance nickel. The manganese is specified as less than 0·6 and silicon less than 0·4, per cent.

J. H. JACKSON and O. W. SIMMONS, assignors to ILLIUM CORPN. *U.S. Pat.* 2,597, 495.

Protection of Nickel-Chromium Steel against Corrosion by Phosphoric Acid

The corrosion of austenitic steels by concentrated phosphoric acid is inhibited by the presence, in solution in the acid, of copper, arsenic, lead, bismuth, silver or iron in the range 0·0005 to 0·2 g. atom of metal per litre of acid.

CALIFORNIA RESEARCH CORPN. *Brit. Pat.* 673,180.

Erosion-Resisting Nickel-base Alloys

Nickel alloys containing small amounts of beryllium and titanium are claimed to have resistance to erosion (e.g., by cavitation). Incidental elements and deoxidizers may be present up to 1 per cent., and in addition one or more of the following elements may be incorporated:—chromium up to 10 per cent., molybdenum and tungsten up to 20 per cent.; thorium, vanadium, tantalum, niobium up to 10 per cent.

HERAEUS-VACUUMSCHMELZE, A.G. *German Pat.* 753,824.

Equipment for Handling Fluids at Low Temperatures

Equipment for storing or conveying fluids at low temperatures (e.g., below −100°C.) is made from a ferritic nickel steel containing 8-20 per cent. nickel, welded with austenitic nickel-chromium alloy rods containing silicon, and from 7-12 times as much niobium as silicon. Suitable electrodes are cited as nickel 75, chromium at least 14, carbon not more than 0·15, niobium 1·0-2·2, per cent., balance (if any)

iron. Some niobium may also be included in the electrode coating. After welding, the structure is preferably normalized at 870°-900°C., re-heated to 785°-800°C. and air-cooled or quenched.

MOND NICKEL CO., LTD. *Brit. Pat.* 677,801.

Corrosion-Resisting Container

A container suitable for handling weakly acidic media is made from a steel containing chromium 20-26, nickel 15-25, molybdenum 1-3, per cent., balance iron, with a carbon content not above 0·06 per cent. Before use such containers should be heated for a short time in contact with a strong inorganic acid. The container is preferably annealed at 1950°F. (1063°C.) and cooled within 3 minutes to below 800°F. (425°C.).

S. G. DEHN, commn. from R. P. SCHERE CORPN. *Brit. Pat.* 672,798.

Brazing of Stainless Steel

Stainless-steel parts are brazed by immersing the assembly, after application of the brazing material (preferably copper), in a molten salt bath consisting of boric acid and cryolite, preferably at 1100°-1120°C.

ROLLS-ROYCE, LTD. (inventor, E. J. WHITEHEAD). *Brit. Pat.* 673,901.

Electrode for Welding Austenitic Steels

A coated welding electrode producing crack-free welds in high-alloy nickel-chromium steels has a core wire of austenitic steel containing magnesium and/or zirconium, preferably 0·005 to 1·0 per cent. by weight. An example given comprises an electrode having a core of a steel containing chromium 18, nickel 12·5, niobium 1·0 (optional), carbon 0·08, silicon 0·3, magnesium 0·01, per cent., balance iron and impurities. The lime-base coating is of the type containing $CaCO_3$ 25-40 parts, CaF_2 30-60 parts, SiO_2 1-10 parts, bonded with Na_2SiO_3.

E. C. ROLLASON, D. F. T. ROBERTS and MUREX WELDING PROCESSES, LTD. *Brit. Pat.* 677,128.

Production of Non-Cracking Hard Facings

On a steel which is to be hard faced with a material of negligible ductility, e.g., nickel-chromium-boron or cobalt-chromium-tungsten, there is deposited an intermediate layer of a cooling-stress-absorbing ductile elastic material consisting of nickel or nickel alloy.

G. F. SCHERER (assignor to ROCKWELL MANUFACTURING CO.). *U.S. Pat.* 2,584,161.

Production of Stainless-Steel Powder

Massive stainless steel (free from carbide-stabilizing elements) is reduced to powder by heat-treating in such a way as to produce carbide precipitation on the grain boundaries, and subsequently making the product the electrode in an electrolytic bath, so as to induce electrolytic intergranular attack. Preferably several electrodes are used and rapid current reversals are made. An 18-8 chromium-nickel steel containing 0·17 per cent. carbon is cited, and the preferred heat-treatment is given as slow cooling from above 1000°C., followed by heating at 500°-800°C. for 1 to 40 hours.

BIRMINGHAM SMALL ARMS CO., LTD. (inventor P. R MARSHALL). *Brit. Pat.* 673,204.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.